Design and simulation high aspect ratio torsion suspension of MEMS z-axis accelerometer

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Abstract. This paper presents new design torsion suspension of MEMS z-axis accelerometer. These prototypes Z-axis accelerometer are based on pantograph lever structure is out-of-plane devices. The results of finite element analysis of the structure are presented.

1. Introduction
An increase in the thickness of the instrument layer of inertial sensors manufactured on SOI structures using the technology of deep reactive-ion etching (DRIE) allows you to create designs with an instrument thickness of more than 100μm and an aspect ratio of up to 1:50 [1]. Such designs can increase the inertial mass without increasing the area of the sensitive element, so that you can reduce noise, increase sensitivity and reduce the cost of the MEMS sensors. Torsion suspensions are widely used in MEMS out-of-plane devices as like micromirrors, accelerometers, energy harvesters, switches.

Thus, the article describes the problem of using high-aspect torsion suspension for acceleration measure.

2. Design of the MEMS acceleration sensor
MEMS z-axis accelerometer is out-of-plane device for measure the acceleration of the perpendicular plane of the substrate. Prototype of this sensors is pantograph lever structure or also scissors lift mechanism. On a macro scale, this mechanism has rigid levers and axial joints; when used in MEMS devices, axial joints are replaced by flexible joints in the form of elastic torsion beams in a simple case.

The topology of MEMS z-axis accelerometer sensitive element is shown in Figure 1. This sensor contains the inertial mass (1), capacity transducer (3), four suspensions of a sensitive element (2) connected to anchors (6). Contact pads (4,5). The inertial mass is 2.8 ng and have linear dimension 500x500x100 microns. The total size of the sensor is 900 x 900 μm, which corresponds to 0.81 square millimeter of the substrate area.
Figure 1. Topology of MEMS accelerometer

A micromechanical gyroscope is made in a silicon volume using the silicon-on-glass technology (Figure 2) and consists of a glass base (8), work silicon layer (1) on which a structure is connected to the glass base through a layer of silicon oxide. Niches were etched in the substrate to ensure mobility of the inertial mass, and a metallization layer pad (5) was applied to provide ohmic contact. The electrode (7) is used to determine the direction of acceleration.

Figure 2. Structure of MEMS accelerometer

The MEMS suspension of the accelerometer is shown in Figure 3a and consists of a lightweight rigid beam 1 and a pair of vertical torsion beams 2 and 3. Torsion beam 2 consists of two parallel connected torsion elements, which allows isolation of torsion strain from bending strain due to the spacing of the primary torsion elements [2,3].
Figure 3. MEMS suspension beam

Figure 3a shows the torsion deformation of high-aspect torsion beams. Modal frequency depends on weight and the stiffness coefficient of construction depending on many parameters including on length, width, thickness of elastic beams and length of rigid beam in the suspensions.

Figure 4. Double beam torsion deformation

The amplitude and stiffness coefficient of the suspension depend on the length of the rigid beam, since the torque on the 2 beam depends on its change.

3. Simulation of micromechanical accelerometer

The result of the finite element modal analysis of pantograph lever structure is shown in Figure 5. The first mode of vibrations with a natural frequency of 7582 Hz corresponds to a deformation perpendicular to the plane.
The second and third modes of oscillation occur in the plane of the silicon wafer at frequencies of 10459 Hz and 10465 Hz, as shown in Figure 6.

The amplitude of displacements was obtained as a result of static finite element analysis and is proportional to the magnitude of the effective acceleration. At 1 g acceleration: 4.5 nm along the Z axis, and 2.2 nm along the X, Y axis. At 10 g acceleration: 46 nm along the Z axis, and 23 nm along the X, Y axis.
4. Conclusion
The design of an integrated micromechanical accelerometer is proposed. This mechanism can be customized to different sensitivity, deviation and range. Customization is achieved by changing the length of the levers thereby changing the torque and deflection, as well as the rigidity of the flexible beams to adjust the range of measurement of acceleration. This makes it possible to manufacture sensors with high sensitivity or high acceleration on a single silicon crystal.

It is also possible to change cross axis stiffness for optimization of structural suspensions can have equal frequencies along three axes and can serve as the basis for a three-axis MEMS accelerometer.

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