DESIGN AND SIMULATION OF A MEMS BASED CAPACITIVE ACCELEROMETER

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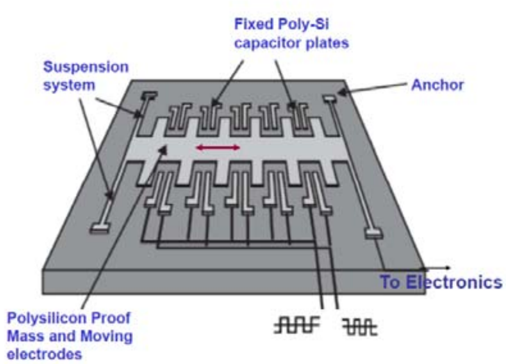
Abstract
The characteristics of MEMS fabrication are miniaturization, multiplicity, and microelectronics. Miniaturization not only allows for small, lightweight devices, but these same devices have high resonant frequencies which mean higher operating frequencies and bandwidths for micro sensors and micro actuators. An accelerometer measures proper acceleration, which is the acceleration it experiences relative to freefall, and is the acceleration that is felt by people and objects. Such accelerations are popularly measured in terms of g-force. At any point in space time the equivalence principle guarantees the existence of a local inertial frame, and an accelerometer measures the acceleration relative to that frame. As a consequence an accelerometer at rest relative to the Earth's surface will indicate approximately 1 g upwards, because any point on the earth's surface is accelerating upwards relative to the local inertial frame, which would be the frame of a freely falling object at the surface
Key words: Capacitive accelerometer, MEMS, Micro sensors, Micro actuators.

I. INTRODUCTION

Micro Electro Mechanical Systems (MEMS) based sensors are widely used for various industrial and domestic applications. MEMS technology is used in the design and fabrication of a variety of sensors to measure acceleration, pressure, force, humidity and temperature. This is due to low weight, compactness and economical nature of these types of sensors. One of the most common mechanical sensing principles is the analysis of the change in parameters associated with the movement of a mass. This principle is predominantly used in accelerometers. The design of accelerometers can be done based on principles of capacitance. With the increasing trend of using accelerometers for smart devices i.e. mobile phones and tablet PCs, the demand for MEMS based sensors is constantly on the rise. An overall compound growth rate of 6.6% in MEMS based accelerometers. The challenge however is to create sensors of high sensitivity while keeping its size and weight to a minimum. The displacement is then measured to give the acceleration. There are many different ways to make an accelerometer. Some accelerometers use the piezoelectric effect - they contain microscopic crystal structures that get stressed by accelerative forces, which cause a voltage to be generated. Another way to do it is by sensing changes in capacitance. Capacitive interfaces have several attractive features. In most micromachining technologies no or minimal additional processing is needed. Capacitors can operate both as sensors and actuators. They have excellent sensitivity and the transduction mechanism is intrinsically insensitive to temperature. . To obtain the pure acceleration due to motion with respect to the Earth, this "gravity offset" must be subtracted. This is generally true of any gravitational field, since gravity does not produce proper acceleration, and an accelerometer is not sensitive to it, and cannot measure it directly. An accelerometer behaves as a damped mass on a spring. When the accelerometer experiences acceleration, the mass is displaced to the point that the spring is able to accelerate the mass at the same rate as the casing. This paper presents simple characterization techniques for capacitive MEMS accelerometer using fabrication technology, single crystal silicon material, comsol 5.3 version software

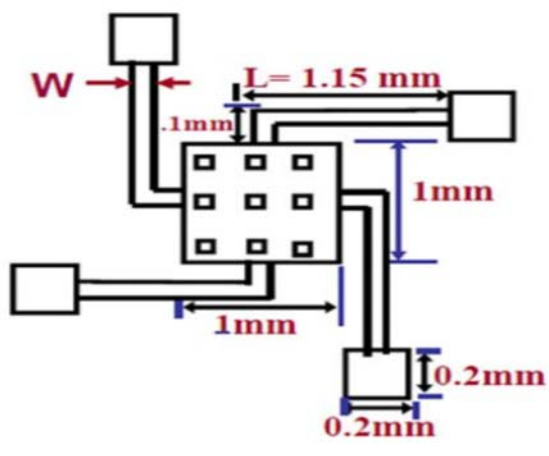
II PRINCIPLE

The main principle operation of accelerometer is the conversion of inertial displacement of a proof mass into an electrical signal. This can be done on a principle of capacitance as shown in the figure1.1. The MEMS accelerometer usually consist of a proof mass suspended using an elastic element when the device is accelerated, an inertial force is applied to the proof mass, resulting in its deflection in the direction opposite to the applied acceleration, this acceleration can be measured from the measurement of the capacitance change between the electrodes.



III. DESIGN

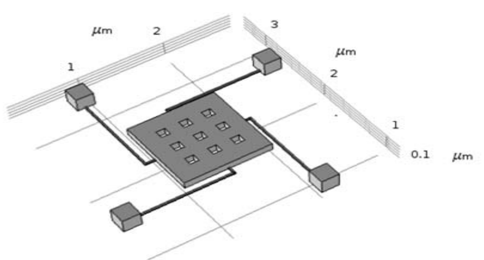
In the capacitive-sensing approach, the mass forms one side of a parallel-plate capacitor and the change in the capacitance of this moving plate with respect to a fixed electrode is used as a measure of a displacement and, hence the external force. The sensitivity in accelerometers using sensors is highly temperature-dependent. Therefore the capacitive-sensing systems are popular and have been widely used by the industry. In this section the focus is on the capacitive-type acceleration sensors. The structure of an SOI based accelerometer consists of a seismic mass and is supported by four folded beams that acts as the spring anchored to the substrate. The effect of location of the folded beam with respect to the square mass is studied using a commercially available FEA software analysis to achieve best Z-axis sensitivity and minimum cross access sensitivity. The analysis has shown that best results can be achieved if the beams are located midway on the square side of the mass. The model named as UZ1 (figure a) have been studied in this context. UZ1 has a seismic proof-mass area of 1*1 mm^2, in micro machined accelerometers, the mass is proportional to the area of the proof-mass structure. The length of the support arm in UZ1 is 1.15 mm. Finite elemental harmonic analysis can be done using ANSYS to study the effects of acceleration and frequency on the deflection of the mass. These results are presented in below figure. It may be noted that the structures UZ1, which has a larger mass and the long supporting beams, gives the best results in terms of sensitivity. The stress analysis carried out has shown that the maximum stress is located in the region where the beam is attached to the mass. The maximum stress estimated using ANSYS is presented in figure it may be noted from here that the maximum stress is highest with structure UZ1 and that it is well within the yield strength of silicon, which is 7GPa.



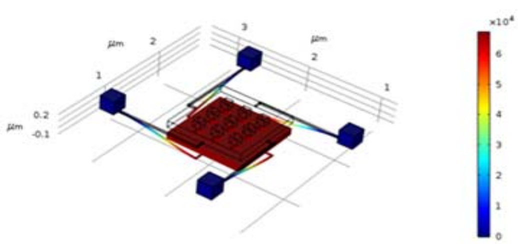
(a) UZ1 Model

IV. SIMULATION

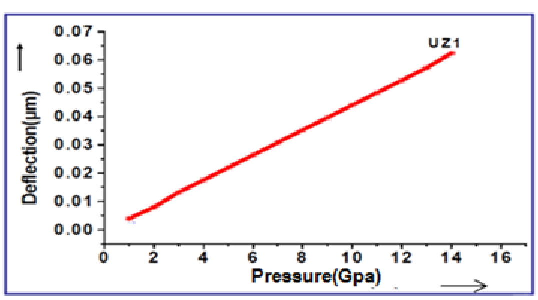
This model designed using comsol software 5.3 version with a solid mechanics and stationary physics. This paper looks at the design and simulation of a MEMS based capacitive accelerometer with dimensions area of proof mass is 1*1 mm^2 , fixed edge block is 0.2*0.2mm, fixed middle block having with a dimension of 1*1mm , length of the support arm is 1.15mm. Finally apply the single crystal silicon material and 7GPa pressure, we get simulated output and then plot the graph for pressure versus deflection along the x-axis and y-axis respectively. The proposed design optimally utilizes the single crystal silicon wafer of a thickness of 100µm. Fabrication can be done with use of minimum masking material and process simplification in mind. The micromachining of the sensing structure can be done with the use of a single mask, thus further simplifying the fabrication process. The device is fabricated on single crystal silicon using bulk micro machining technology.



(B) Schematic model with single crystal silicon material



(C) Design output of capacitive accelerometer



(D) Variation of the Pressure v/s Deflection

VII.CONCLUSION

MEMS accelerometers are inertial sensing devices that address the high performance, low power, integrated functionality and small size requirements in countless applications. Intelligent sensor accelerometers offer further integration and improved performs including application targeted functionality, comprehensive factory calibration that saves costs and production test time and a simple programmable interface that ensures highly precise integration that is simple to implement. Standardization of production, testing and packaging MEMS would certainly do a big part at it. The relatively long and expensive development cycle for a MEMS component is a hurdle that needs to be lower and also less expensive micro fabrication method has to be pursued.

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