Using the Effect of Mechanical Stress on Doped Silicon as an Angular Movement Sensor for MOEMS/MEMS Micro Mirrors

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Abstract

The effect of elastic strain of moderate magnitude using high doped silicon substrate can change the conductivity of the substrate. The commonly used metal (strain) gage has a magnitude factor of between 2 ÷ 4 while high doped silicon (strain) gage factor magnitude is between 150 ÷ 200, thus improving the substrate sensitivity considerably. Using those physical attributes allow us to create a MOEMS sensor resolving accuracy issues and saving space in any future MOEMS device design. Those devices will be able to measure any mechanical movement connected to the high doped silicon substrate by converting the physical strain created from the movement stress to current/voltage change in the substrate device. The simplicity of the device is that the device could measure movement without any need to implement an outer sensor to it. By measuring the device's strain change it would "feel" the movement and convert it to an analog value, thus creating a strain gage built in the MOEMS device surface.

Index terms— an analog value, thus creating a strain gage built in the MOEMS device surface.

1 Using the Effect of Mechanical Stress on Doped Silicon as an Angular Movement Sensor for MOEMS/MEMS Micro Mirrors

Introduction any of the MOEMS (Micro Optic Electric Mechanical System) development is micro mirrors devices that display an image or a video signal on a screen. Those devices usually use small sensors such as PSD (Position Sensitive Diode). Many of those devices encounter difficulties due to sometime pour image focus that derives from the difficulty to close the closed control loop between the mirror movements to the actual mirror position. Also those sensors are relatively quite big in the mirror device.

We wanted to create a "built in" sensor implemented in the mirror base rod substrate, thus simplifying the device and improving the sensor's reading and the image quality.

In order to measure angular movement of a micro mirror placed on a micro rod a mechanical stress conversion is needed. The stress resulting angular movement is torque stress, and in order to easily measure small strain change in the substrate we needed to convert it to a linear torsion or compression stress.

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2 Mechanical Stress Transformation of Torsion to Tensile and Compression

Converting the torsion stresses to tensile and compression stresses was done by using new mechanical connection between the main beam of the mirror and its end connection. The new structures at the end connection were shaped as "H" for the micro mirror main beam. This solution is an originally development we invented and proved as very useful.

Getting a linear stresses distribution on a large surface made it easy to measure without limiting the micro mirror movement requirements. The constraint design of main mirror beam was very basic. The cube shaped connection gave no room for implanting any sensors or to create big surface to measure stresses. L 2 L x V(x) 0.5L L L M 0 ? 2 0 M 2 0 M ? x x M(x) y(x) x L M x M ? ? ? 0) (? ? ? ? L h b x M h b h x L M I C M x ? ? ? ? ? ? ? ? ? ? ? ? ? 2 0 6 12 3 2 0 ? dx du xx ? ? ? ? ? ? m m u h b E L M L L h b E M u x L h b E M L L dx L h b E x M u 013 .0? ?

Calculation shows the same maximum elongation for the other half of the beam.

Both half beams are symmetric up to a sign difference.

The elongation is big enough to be effective and measurable by our sensor application. The maximum strain of half a beam is: III.

3 Electronic Design

4 High Doped Silicon as a Strain Gage

The Electrical Principle of operation in order to create the built in sensor was first of all adding beams for the "H" constraint, thus adding big surfaces that are easier to implant MEMS sensors on. Secondly using high doped silicon to increase the conductivity of the substrate, thus enhancing the sensitivity of the built in sensor in the substrate. The gage factor of metal is between 2 ÷ 4 while the high doped silicon gage factor is between 150 ÷ 200. Thirdly using Wheatstone bridge to precisely measure the small changes in the resistance of the material due to applied stresses derived from angular movement. Another use of the Wheatstone bridge is to compensate temperature interferences and noises.

For high doped silicon New added beam dimensions: but our elongation measurements were done for half beam so we shall use in our calculations.

For gage factor 150 we get resistance delta of:

V.

5 Fabricating a Prototype Model

In this project the device was designed, masks were fabricated and manufacturing process flow was created for this specific model. Masks were fabricated in micro fabrication labs of Tel Aviv University, lithography, Dry Etch, Wet Etch and the production process was done in the labs. The process was unique and included complicated design and fabrication with Critical Dimensions as small as 10?m with depth of 70?m. The highly doped silicon substrate amplified the sensitivity of the measurement areas, thus enabling easier way to measure small angular movements of the micro mirror. ? ? ? ? ? ? ? ? ? ? ? ? ? m m L h b E M u L L h b E M L L h b E M L L h b E M u x L x L L L L h b E M dx L x h b E M u? 033 . 0 2 78 . 0 013 . 0 2 max max ? ? ? ? L L ? R 3 R 4 ??????? R3 R4 R3 R4 Compression Tensile Tensile Compression R1, R2 ??????×?"? S V V S 1 2 0 ? ? ? ? S V V S 1 2 0 ? ? ? ? ? R R S ? ? ? ? ? ? ? ? ? ? ? d R dR d ? ? ? ?? 1 ? R R L L R R S G F ? ? ? ? ? ? ? S GF ? cm ? ? ? ? ? ? 1 10 2 10 ? S R h ? ? b L S R b L h A L R ? ? ? ? ? ? ? L=780?m=0.078cm, L/2= 0.039cm b = 20?m= cm 3 10 2 ? ? , h = 70?m= 3 10 7 ? ? cm ? ? ? ? ? ? ? ? ? ? ? ? ? ? 5 . 278 3 10 2 2 10 9 . 3 3 10 7 2 10 b L h R ? ? ? ? ? ? ? ? ? ? ? ? 1392 5 . 278 033 . 0 150 max R G F R R R G F ? ?

The new device is simpler and takes smaller space then the old one (with the PSD).

6 VI.

7 Conclusion

The new design of built in sensor on silicon substrate as a strain gauge is new and innovative. It can change the method of MEMS measurements for micro mirrors and other applications. Those measurements are essential for closed loop control systems used in micro moving system applications. We hope this project will make it easier to develop devices for scanning images on small screens such as glasses, small projectors etc or any other MEMS designs it might have an effect on. [1] [2]

[2]Using the Effect of Mechanical Stress on Doped Silicon as an Angular Movement Sensor for MOEMS/MEMS Micro Mirrors

Figure 1: M

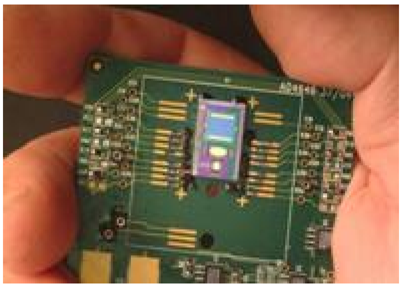

Figure 2:

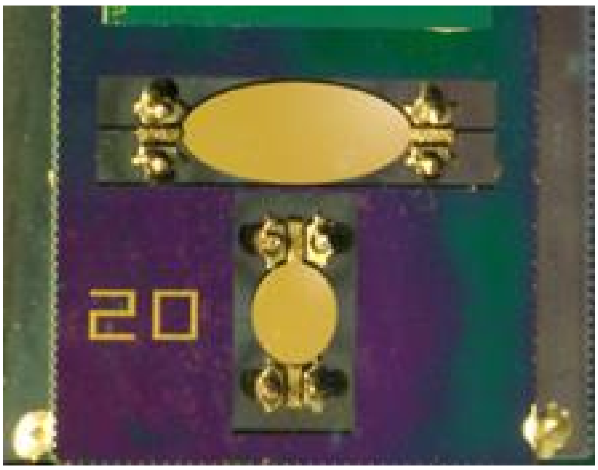

Figure 3:

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