MEMS Humidity Structure with Cantilever - Simulation of Behaviour

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ABSTRACT

The aim of this paper is to report the design of the simple polymers structure humidity sensors. For precise simulation and modeling of Micro Electro Mechanic Systems (MEMS) is used integrated set of tools in programme CoventorWare. We have designed two difference sensor models. The primary part of first structure sensor is microcantilever and the primary part of second structure sensor (SAW) is interdigital transducer. We have made its mechanical and piezorezistive simulation for the first structure. Acquired simulation data gets a primary image about sizes bend and surface strain on micro cantilever which forms sensing part of sensor. A new approach to structure simulation and model creation was used. New structure arrangement of humidity sensor was used.

Keywords: MEMS, simulation, humidity sensor, cantilever, SAW

1 INTRODUCTION

For precise simulation of Micro Electro Mechanic Systems (MEMS) is used integrated set of tools in programme CoventorWare. These tools allow user to design, simulate and subsequently specify design of (MEMS) structures.

The primary part of structure sensor is microcantilever made of thin silicon wafer which has a rectangular shape. With help of applying process we spread thin layer of the hygroscopic polymer materials such as polyamid, polyimid. This microcantilever is fixed on the immobility silicon base (Figure 1) [1].

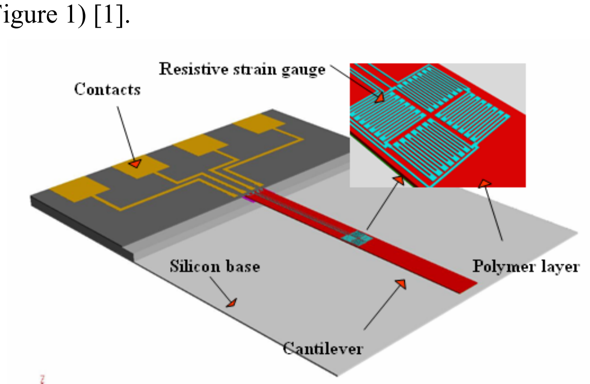


Figure 1: Microsensor structure.

The humidity which is contained in surrounding gas reacts with hygroscopic polymer material deposited on the surface of microcantilever. In this layer occur reversible mechanical changes (contraction, extension), that create stress in microcantilever and force it to fold down [2].

Surface acoustic wave (SAW) sensors, which are sensitive to a variety of surface changes, have been widely used for chemical and physical sensing. All acoustic wave devices and sensors use a piezoelectric material (PVDF, guartz SiO_2, $LiTaO_3$, $LiNbO_3$, PZT) creates a mechanical stress. Piezoelectric acoustic wave sensors apply an oscillating electric field to create a mechanical wave, which propagates through the substrate and is then converted back to an electric field for measurement.

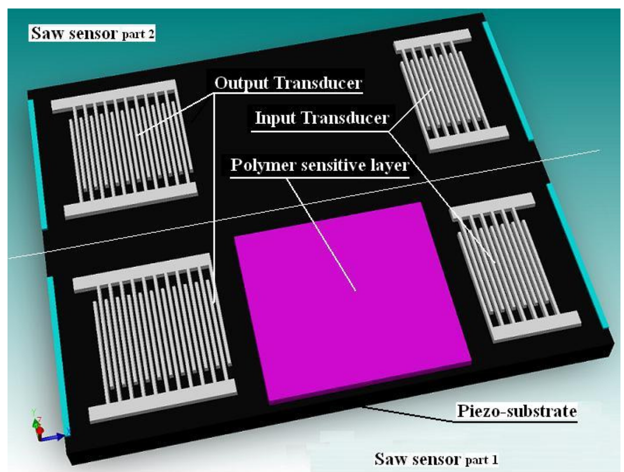


Figure 2: SAW-sensor structure.

Two pair of symmetrical interdigital transducer (IDT) are the most usually used design for generating and receiving waves by exploiting the piezoelectric effect of the substrate as is illustrated in Figure 2. A SAW transducer consists of two interdigital arrays of thin metal electrodes deposited on a highly polished piezoelectric substrate. The electrodes that comprise these arrays alternate polarities so that an RF signal of the proper frequency applied across them causes the surface of the crystal to expand and contract. This generates the Rayleigh wave, or surface wave, as it is more commonly called [3].

In its simplest form, a SAW device appears as two comb-like metal structures deposited on a piezoelectric crystal surface (Figure 2 - Saw sensor part 1) and humidity sensing is reached by detecting changes in the sensitive layer which perturbing the surface acoustic wave channel.

The ability to control or compensate for the many surface forces has been instrumental in collecting valid data. In cases in which it is not possible to neglect certain effects, such as frequency drift with temperature, methods such as the "dual sensor" technique have been utilized (Figure 2 - Saw sensor part 2).

2 SCANNING OF BEND ON MICROCANTILEVER

The first way of scanning bend on microcantilever is using resistive strain gauge connected into Wheaston bridge (Figure 1), which is located in the place with the biggest surface strain because of the biggest change resistivity. There are two ways how to produce the resistive strain gauge. The first way uses litography process - we deposit thin layer of metal on the surface polymer material. Second way uses fotochemical process - it creates structure of strain gauges made of another conductive polymer material. For evaluation of resistive change in the structure of resistive strain gauge we use Ohm act [4].

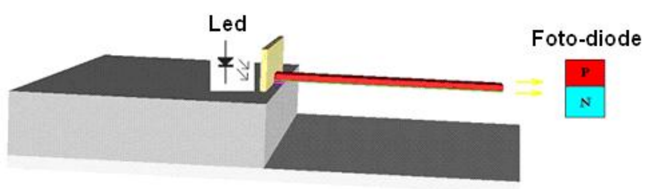


Figure 3: Sensing – using LED and Fotodiode.

Another way of scanning bend on microcantilever is using an impact location change of ray of light onto foto-diode. The silicon cantilever represents waveguide in this structure (Figure 3). This structure is using the LED as a source of radiation. This LED generates light in wave-lenght 1.3 µm. It is for reason of minimal absorption loss in silicon microcantilever. Germanium diod is used as a detector of light, which is sensitive on the side of PN junction.

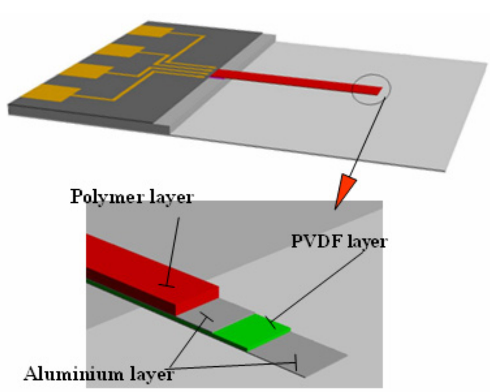


Figure 4: Sensing – using PVDF layer.

Another way of scanning bend on microcantilever is using electric polarization arising from PVDF (piezoelectric polyvinyliden film) material, which forms microcantilever base (Figure 4). On the surface of microcantilever we can deposit thin layer of polymer material with using the one of the most depositing process.

3 SIMULATION AND RESULTS

In the programme CoventorWare it is not possible to simulate bend on microcantilever caused by humidity. Instead we use pressure, which effects on the surface of cantilever arising in polymer layer in this programme. To calculate value of this pressure we use base figure for calculation of value of relative humidity and derivative figure for calculating value of saturation pressure.

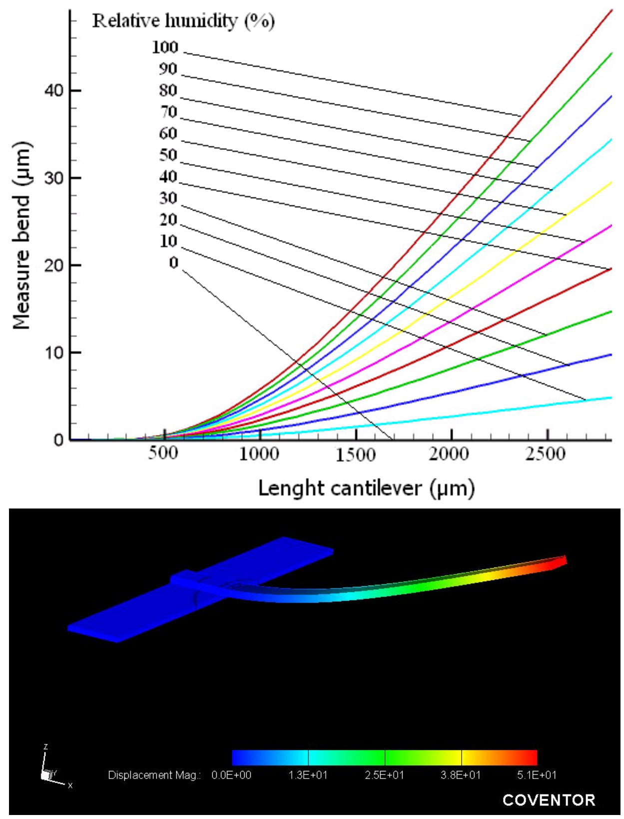


Figure 5: The results of mechanical simulations 1.

$$RH = \frac{P_{abs}}{P_{sat}} 100 \tag{1}$$

$$P_{sat} = 610.78 e^{\left(\frac{t}{t+283.3} 17.2694\right)} \tag{2}$$

where: RH (%) is relative humidity, P_{abs} (Pa) is absolute pressure, P_{sat} (Pa) is saturation pressure, t (^{0}C) is temperature.

After induction of equation (2) into equation (1) we get equation for absolute pressure. This pressure depends on temperature and humidity. All simulation data were design for changing value of relative humidity with temperature t = 25 ^{o}C [5].

From the mechanical simulations we got important information about size of bend (Figure 5) and surface strain (Figure 6) on microcantilever cause by humidity [4].

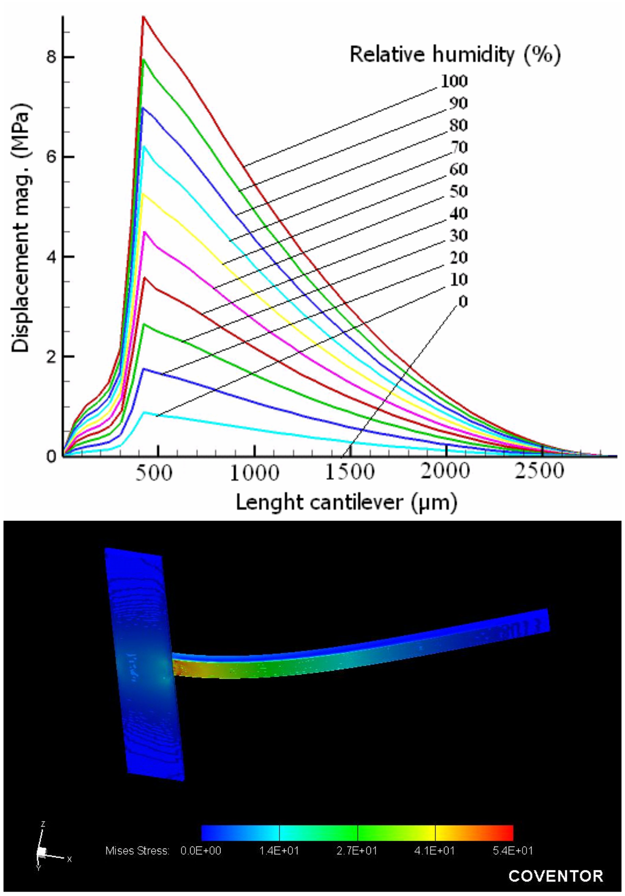
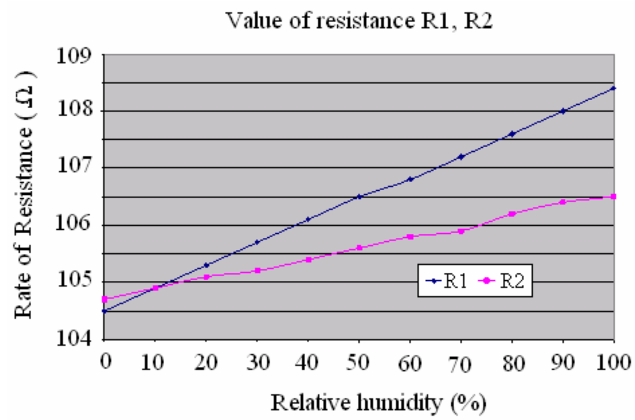


Figure 6: The results of mechanical simulations 2.

From the piezoresistive simulations we got information about changes of resistivity values in axials and crosswises strain gauges (R1 and R2) placed in Wheaston bridge (Figure 7). These changes were caused by surface straining evoked by bending of microcantilever (Figure 7). [6]

From measured value of resistive strain gauge it is possible to calculate and picture a course of potential V_m, which depends on change relative humidity (Figure 8).



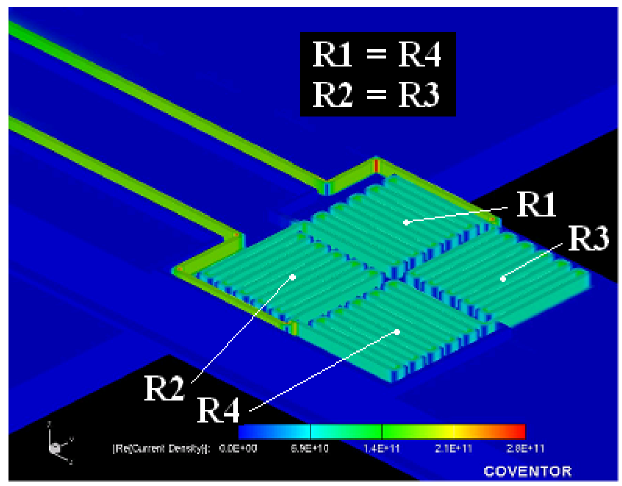


Figure 7: The results of piezoresistive simulations.

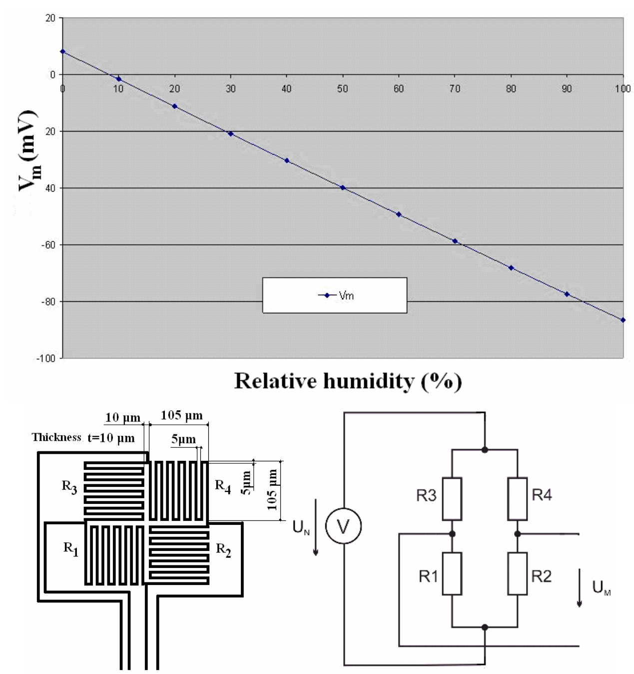


Figure 8: The results of piezorezistive simulations.

4 CONCLUSION

This work is oriented on the design and modeling of microsensors structure, which changes its geometric dimension caused by humidity. Acoustic wave sensors are extremely versatile devices that are just beginning to realize their commercial potential. They are competitively priced, inherently rugged, very sensitive, and intrinsically reliable, and can be interrogated passively and wirelessly.

The main aim of this work was the humidity sensor, which has cantilever structure. With this structure we did mechanical and piezoresistive simulation in programme CoventorWare. This simulation gave us information about size of microcantilever bend and size of surface straining on the cantilever surface and resistivity changes in resistive strain gauges. From the simulation datas we found, that the bend of microcantilever was 0 - 50 μm range and displacement mag. were 0 - 8.5 MPa while the relative humidity change was 0 – 100 %.

Another stage of this work will be aimed on designed structures realization and their characterization, which will be compared to simulated data.

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