Computer-Aided Optical Detection for Silicon Mems Pressure Sensor

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Abstract – **In the paper a computer-aided optical detection for a new MEMS pressure sensor has been presented. Preliminary tests of the pressure sensor integrated with the components of the optical detection system and software has showed accurate detection of pressure by purely optical system.**

Keywords – **pressure sensor, optical detection, MEMS.**

I. Introduction

Silicon MEMS pressure sensor have found wide application in medical, automotive, industrial, military equipment and consumer devices such as smartphones. However, most commonly used piezorezistive and capacitive pressure sensors, cannot be used in difficult environmental conditions like: high temperature, strong electromagnetic fields, ionizing radiation. Measurements in a harsh environment require the use of a pressure sensor with a new design as in [1]. In this case optical measurements techniques have many advantages over the others methods. Optical measurements techniques are noncontact, nondestructive, small temperature effects and adaptive in harsh environment.

II. Principle of Operation and Construction of Optical Pressure Sensor

A new MEMS pressure sensor has been developed at Wroclaw University of Technology [2]. The sensor consist of three parts: silicon membrane, glass spacer and silicon perforated membrane with via holes array and central large via window (Fig.1).

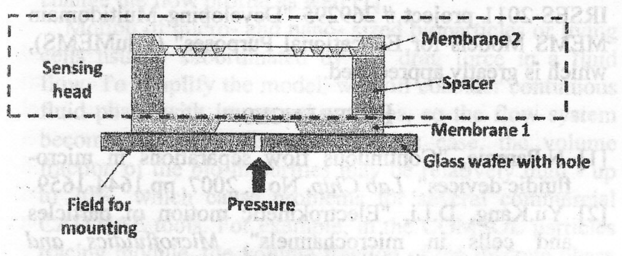

Fig. 1 Scheme of the sensor

The sensor works as follows: a laser light beam, coming from the distanced light source illuminates the membrane 1 (Fig. 2). The deflected under external pressure membrane 1 reflects light what results in trespasses through via holes array in membrane 2, generating the specific pattern that can be observed by the CCD mini camera or directly by a human eye.

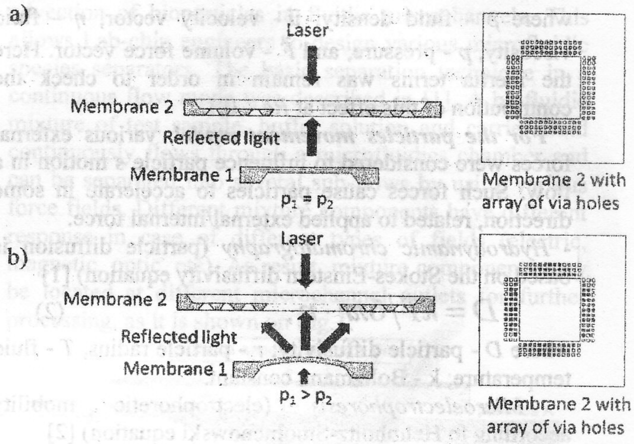

Fig. 2 Scheme of the detection system and the model points of light observed at membrane 2: a) the light reflected from the flat membrane sensor - no points of light, b) the light reflected from the deformed membrane - a characteristic light pattern (filled squares)

As the light source and the detecting CCD array sensor are placed at least several tens of centimeters away of the sensing parts (e.g. membranes and the spacer), the presented here system is especially suitable for such application in which a direct sensing method cannot be applied.

The sensor is made of silicon and glass with the use of the microengineering techniques. Membrane 1 (5×5 mm^2 and a thickness of 20 and 30 μm) and membrane 2 ($10 \times 10 \times 0.125$ mm^3), were made in the double-sided polished silicon substrate with a crystallographic orientation (100) and a thickness of 400 microns. In the membrane 2 the central window (5 x 5 mm^2) and holes array with dimensions 60 x 60 μm^2 was formed. Each hole of the array, in the membrane 2, is formed by (111) planes, angled 54.74° to the surface of the membrane 2. The process utilizes double-side deep wet etching (80°C, 10M KOH) of a silicon. Silicon parts are bonded together with glass spacer as shown in the Fig 3.

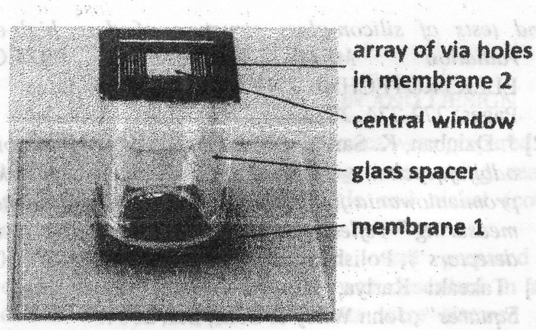

Fig. 3 Sensor at glance

III. EXPERIMENT

The configuration of the test bench is clearly shown in Fig. 4. In tests as a light source semiconductor laser (λ = 532 nm) was used. Distance between laser and membrane 1 is 25 cm. To illuminate the entire surface of the membrane 1 laser beam has been expanded and collimated by a lens system. Camera with objective is placed 30 cm from membrane 2 under angle α versus optical axe as shown in the Fig. 4.

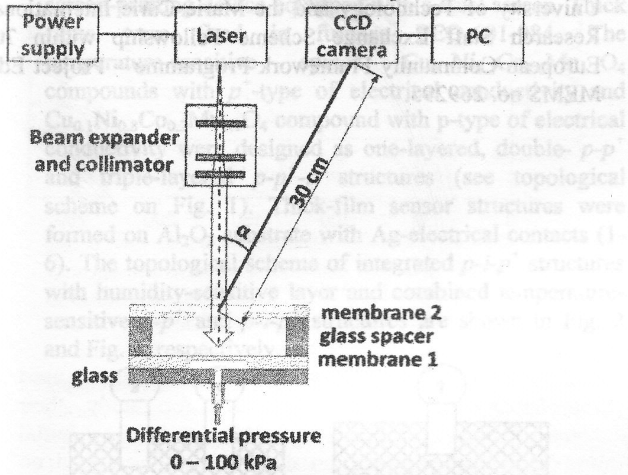

Fig. 4 Measurement set-up

Experiments have confirmed proper work of the sensor. Light pattern onto membrane 2 was observed. Shape of the pattern changed with increase pressure as expected (Fig. 5).

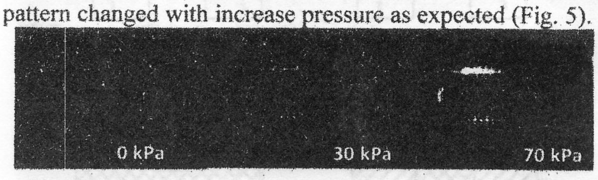

Fig. 5 Light patterns observed on the membrane 2 for different pressures

The main principle of the work of the presented here sensor is based onto an analyze recognition at light- generated pattern onto perforated membrane by a specialized software.

The software is written in C++ programming language (using Qt graphical framework for GUI) for better compatibility with hardware. It provides user-friendly interface (Fig. 6) for viewing and processing video data from measurement set-up.

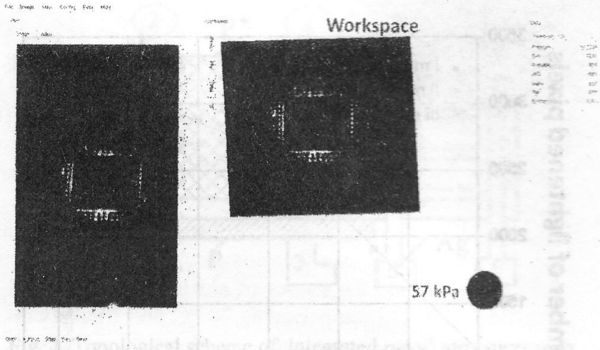

Fig. 6 Software GUI

As mentioned above the software should analyse pattern shape and number of ligtened pixels on the membrane 2 being proportional relation to a pressure deflecting the membrane 1. This is related to equation [1]

$$p = A \cdot e^{Bn}, \qquad (1)$$

where: p – is pressure under membrane 1, n – is number of light points, A, B – is a constants. A and B values are calculated based on data from a set of images with given pressure values by least squares approximation method [3] that is used for solving of overdefined systems of equations. The function is used for approximation of pressure from a calculated number of light points on specific image from CCD camera. The output data is presented in alphanumerical form or as a graph. The advantages of used approach are simplicity of implementation and speed. The disadvantages are low precision and dependence from camera placement angle.

IV. RESULTS AND DISCUSSION

Software has been tested in measurement set-up described earlier. First, images for known values of pressure have been analyzed and calibration curve has been calculated (Fig. 7).

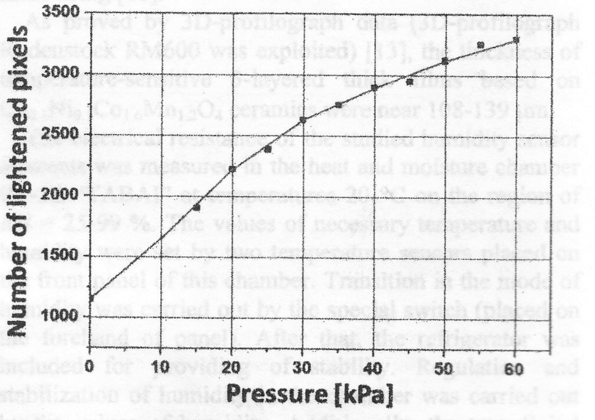

Fig. 7 Number of lightened pixels versus pressure (membrane 1 thickness 20 μm) - calibration

Based on this calibration curve the unknown pressure value have been calculated (Fig. 8). Measurement confirm a proper work of the software.

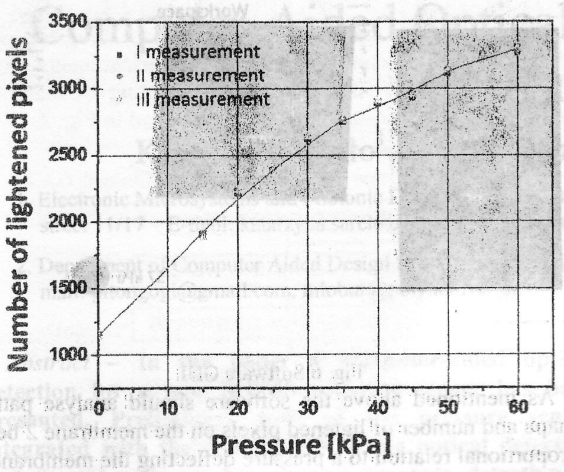

Fig. 8 Number of lightened pixels versus pressure (membrane 1 thickness 20 μm)

Currently, the software works with data indirectly. But it is planned to add direct connection between software and the CCD camera to obtain results in real-time.

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V. CONCLUSIONS

In the article first version of the software for MEMS pressure sensor with optical detection has been presented. Experiments confirmed proper work of the sensor with the developed software but there is a space for future improvements connected to the automation of processing.

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