PRESSURE SENSOR WITH SI_3N_4 DIAPHRAGM AND OPTOELECTRONIC SENSING

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Abstract – Sensitive pressure sensor with nitride membrane and optoelectronic read-out system is described. Measured pressure is transformed into thick layer nitride membrane deflection. Nitride membrane serves as a mirror for laser beam and can move reflected laser mark. Mark's position is sensed using position sensing device – fotolateral diode. Diode double current signal is amplified and conditioned digitally by ADuC 812 microcomputer. This one chip microcomputer provides an IEEE 1451.2 interface.

Keywords – pressure, nitride membrane, optoelectronic, standard IEEE 1451

1. INTRODUCTION

A microelectronic sensor for low-level pressures measuring is a problematic matter. There are technological troubles with creating a pressure sensor with a silicon diaphragm for sensing pressure under 5 kPa. A silicon diaphragm displacement or internal stress may be too small to affirm an adequate accuracy and resolution for capacitive or piezorezistive read-out technique. Secondly, most piezoresistive sensors and some capacitive, are quite temperature sensitive and require additional thermal compensation.

Using suitable diaphragm and measuring the distortion caused by the external pressure usually do acquisition of the pressure. The distortion, as a non-electrical quantity, is converted to the change of resistance with piezo-resistive sensors, or it can be measured by determination the change of capacitance formed by coated layers of the diaphragm vs fixed plate. The principal advantages of capacitive pressure sensors over piezoresistive pressure sensors are increasing pressure sensitivity and decreasing temperature sensitivity. However, excessive signal loss from parasitic capacitance is a serious disadvantage, which hindered the development of miniaturized capacitive sensors until on-chip circuitry could be fabricated.

Optical methods exploit changing intensity of modulated light caused by the external pressure. An optical readout has several advantages over other technologies – a simple encapsulation, small temperature coefficients, high resolution and accuracy. Especially promising are the optoelectronic sensors operating with the light interference phenomena. Many diaphragm-based optical sensors have been reported which measure pressure induced deflections using Mach–Zehnder interferometry and Fabry–Perot interferometry. Drawback of this solution is a relative difficult design.

2. DETAILED DESCRIPTION

For increasing pressure - displacement sensitivity, we use LPCVD silicon nitride (Si_3N_4) diaphragm created on the Si (100) wafer.

As a read-out sensing system we apply an original optical principle. Applied pressure deflects the nitride membrane. Reflected laser beam changes the position of the focused laser beam mark (see Fig. 1).

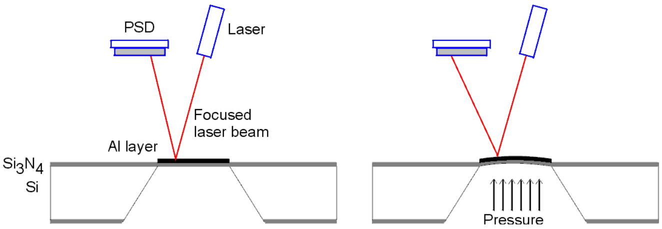

Fig. 1. Pressure measurement using reflected laser beam

SiTek PSD sensor measures position of the laser beam mark. Spot position is determined by dividing the difference of the output current signals with the sum of the output current signal. Advantages of this solutions compared ton the other optical methods are significant and resulting in increasing of the sensitivity and automatic temperature compensation. In contrast to another solutions we measure a position of the laser beam. The temperature influence to intensity change of the laser light does not affect the light spot position.

Sensor output current signal is conditioned digitally using Analog Devices ADuC812 microcomputer. This one chip microcomputer provides calculation of the position of the light spot, converts this position using an internal table on the measured pressure and creates an IEEE1451.2 interface, too.

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3. REALISATION OF THE SENSOR

An LPCVD silicon nitride (Si_3N_4)A is used for sensing pressure element – membrane manufacturing. A standard method is used for fabrication of a free-standing membrane. The clean (100) wafer is coated with 160 nm of silicon nitride prepared by low-pressure chemical vapour deposition (LPCVD). A square window pattern is opened on the wafer back using an electron lithography technology. The silicon is then etched away using an anisotropy etchant composed of 46 % KOH and water dilution [2].

Source of the laser beam is microelectronic laser *FLEXPOINT 67/1AF-AV* with glass lens for laser beam focusing. Laser wavelength is λ = 620 nm (red light) and power 0,4 mW.

PSD (position sensing device) is a product of the SiTek Electro Optics, type 1L5SP – one-dimensional sensor. The PSD is a lateral photodiode in that incident light generates photoelectric current. This current flows in the active area and appears at the two electrode. The current to each electrode is inversely proportional to the distance between the incident light position and that electrode.

PSD currents are amplified with operational amplifier AD822 (see. fig. 2) and output voltage is fed to the input of the ADuC 812 microprocessor A/D converters.

The ADuC 812 microprocessor is a basic building block of our “pressure smart sensor”. This product includes on-chip high performance multiplexers, ADCs, DACs, FLASH program and data storage memory, an industrial standard 8052 microcontroller core and support several standard serial ports. The microcontrollers may also access to nonvolatile memory that contains a “TEDS” field (Transducer Electronic Data Sheet) and to ten wire TII (Transducer Independent Interface).

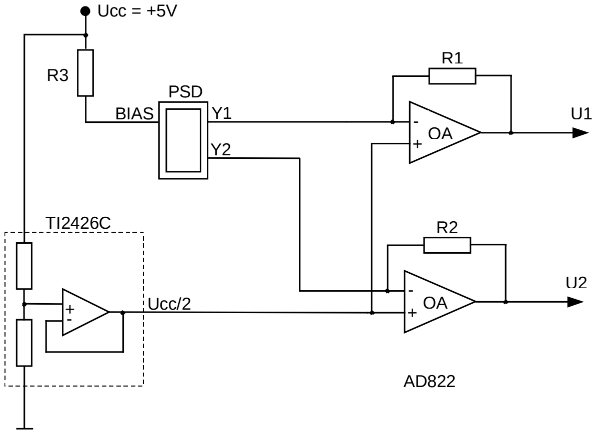

Fig.2. PSD sensor signal conditioning

The dimension of our pressure sensor is compromise between sensitivity (if we increase length of the laser beam path, we increase sensitivity) and overall size. Parameters of the constructed prototype were – length of the laser beam 175 mm, sensitivity of the diaphragm position 0,1 nm. A prototype design is shown in Fig. 3.

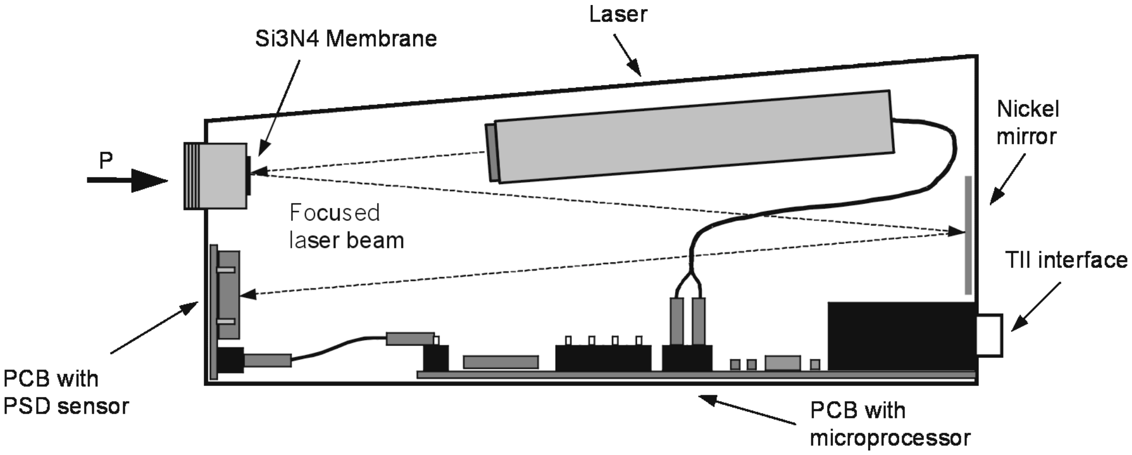

Fig. 3. Design of the pressure sensor prototype

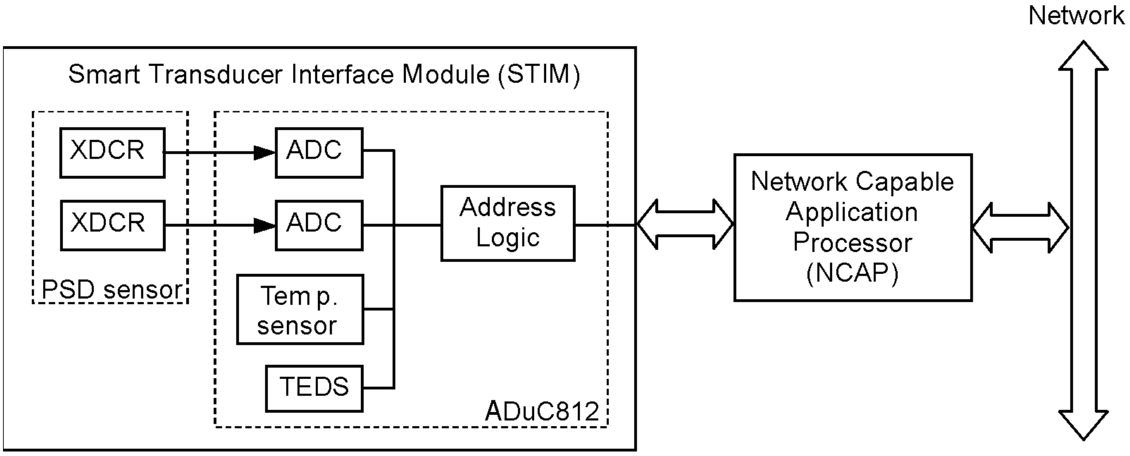

Fig.4. IEEE 1451.2 Implementation on the pressure sensor

4. IEEE 1451 IMPLEMENTATION

Fig. 4. shows basic components of an IEEE 1451.2 compatible system. Our pressure sensor is referred to as a “STIM” (Smart Transducer Interface Module). The STIM contains the TEDS which stores sensor specifications, transducers (XDCR) - temperature and PSD sensor, necessary signal conditioning and as analogue-to-digital conversion, simple discrete digital input/output (DI/O), and logic circuitry to facilitate digital communication between the STIM and NCAP (Network Capable Application Processor). Through a 10-wire digital communication interface TII, the NCAP or networked host can initiate sensor readings, as well as request TEDS data. The NCAP supplies STIM up 75 mA at 5V.

RESULTS

New type of optical read-out technique for pressure sensors with thin nitride diaphragm has been developed and tested. Main advantages of the sensor are wide dynamic range of measured pressure with excellent resolution. LPCVD silicon nitride films are the highest quality films available in the sensor industry as an insulating and protective films, diaphragm resonant frequency is high because it has a large residual tensile stress. IEEE 1451.2 capabilities was implemented in our pressure sensor.

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