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SAW-Pirani vacuum sensor with extended range and sensitivity

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Pressure sensors for a broad pressure range are needed for pressure monitoring and control in different applications of vacuum technology. Miniaturization of sensors helps to produce minimally invasive devices that preserve the vacuum level within the installations [1]. Thanks to the wide use of silicon micromachining, significant progress has been made in the miniaturization of thermal vacuum sensors [2-4]. Various micro machined subatmospheric pressure sensors based on different physical principles have been proposed [5-7]. In most cases, these systems can only be operated in a very specific pressure range below atmospheric pressure [8-11]. Among them are Pirani sensors and Surface Acoustic Wave sensors.

With a Pirani sensor the pressure dependent thermal conductivity of the gas surrounding the sensor is measured. When a heated element such as a wire, a plate or a chip is in contact with gas molecules, a heat flux will be established to those molecules being proportional to the molecular density of the gas and therefore to the pressure. Measuring the temperature variation of the element allows measuring the pressure.

A Surface Acoustic Wave (SAW) sensor is measuring the pressure dependent frequency shift of a wave exciting a piezoelectric substrate. SAW are elastic waves that propagate on the surface of piezoelectric crystals. Their propagation frequency and elastic constants are sensitive to the properties of the surrounding environment. The general design consists of an interdigitally structured transducer printed on the surface of a piezoelectric crystal which then converts a voltage into a SAW and vice versa. SAW devices offer a lot of opportunities of wireless operation [12-14], which are, in most cases, not yet explored.

In this paper, a micro wireless vacuum sensor is presented to be operated between high vacuum and atmospheric pressure. The sensor combines the Pirani principle and Surface Acoustic Waves.

The sensor design depicted in Figure 1 consists of a 1 cm^3 compact polymer cube crossed at its center by a microchannel. A SAW-Pirani chip is inserted inside the microchannel having 500 µm hydraulic diameter and is used for pressure sensing. The chip is heated via a Joule resistance printed at its bottom. A wireless heating coil and an interrogation antenna are inserted inside the core of the sensor. Due to the compact geometry and the integration of commercially available electronic components, the device can be integrated into microsystems as well as macrosystems.

The new sensor will be operated as follows: the SAW-Pirani chip inside the microchannel is heated via the Joule resistance at its bottom. The energy for this is obtained wirelessly from the coil beneath. An interrogation signal is sent to the sensor via the interrogation antenna using a Network Analyzer. The reflected signal including a frequency shift is received back by the same antenna. A processing algorithm calculates the pressure from the frequency shift.

The sensor was designed and simulated with COMSOL, and manufacturing and assembly of a prototype was performed. The SS2467BB3 sensing chips shown in Figure 2 have been manufactured by the company SAW Components (Dresden, Germany). These chips have been tested at atmospheric pressure, and their resonance frequency has been identified by a frequency sweep using an Agilent E5071C Network Analyzer. Figure 3 shows the S11 reflection coefficient close to the resonance frequency of 2.45 GHz.

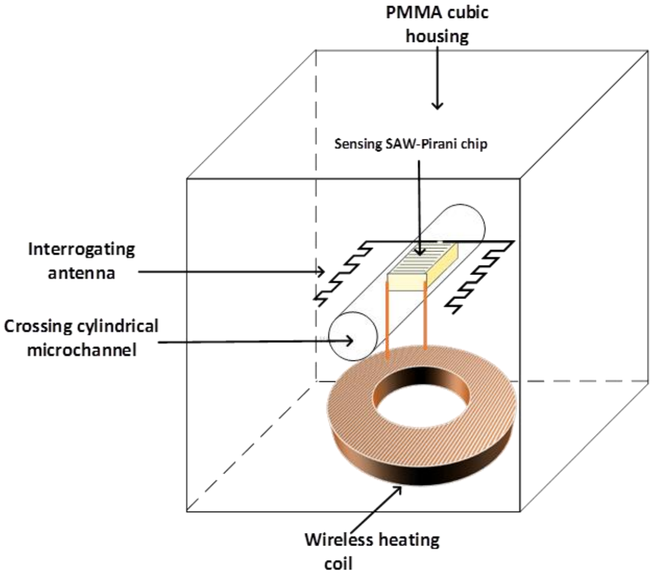


Figure 1. *Design of sensor*

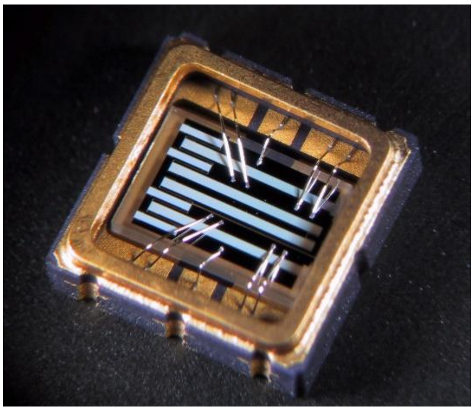


Figure 2. *SS2467BB3 Chip from SAW Components*

Afterwards, the frequency shift of the chips due to temperature variations was tested. The temperature was variated using heat plates. The chips were then introduced into a vacuum environment and wireless interrogation via antennae was tested. Finally the chip was connected to the heating coil and wireless heating was implemented on it. Figure 4 (a) shows the receiving coil inside the sensor and Figure 4 (b) shows the transmitting coil for the wireless heating.

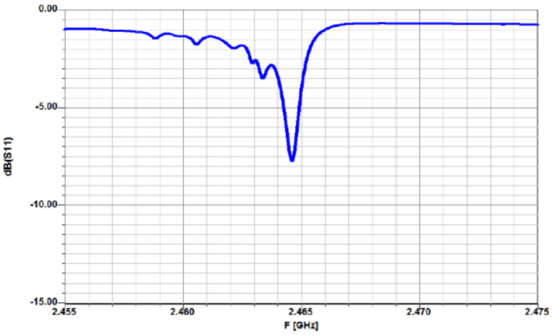
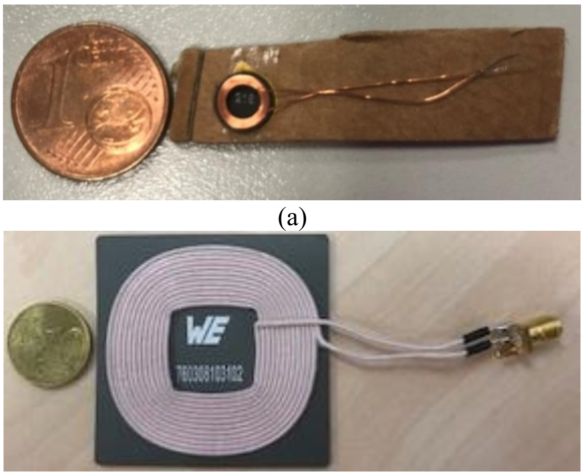


Figure 2. *S11 of the chip at atmospheric pressure and room temperature near the resonance*



(a)

(b)

Figure 3. *Heating power supply (a) Receiving coil (b) Transmitting coil*

A 2.45 GHz interrogation antenna has been designed to fit inside the sensor with adjusted power gain and correctly matched to the chips. The antenna allows interrogation from a distance of about 10 cm [15].

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