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DESIGN OF A SAW PIRANI SENSOR WITH EXTENDED RANGE AND SENSITIVITY

Sofia Toto[1], Pascal Nicolay[2], Gian Luca Morini[3], Juergen J. Brandner[1]
[1]Karlsruhe Institute of Technology, Hermann von Helmholtz Platz 1, 76344 Eggenstein Leopoldshafen, Germany
sofia.toto@kit.edu, juergen.brandner@kit.edu
[2]Carinthian Tech Research, Europastrasse 12, 9524 Villach, Austria
pascal.nicolay@ctr.at
[3]DIN, Alma Mater Studiorum Universita di Bologna, Viale del Risorgimento 2, 40136 Bologna Italy
gianluca.morini3@unibo.it

KEY WORDS

Pressure sensors, vacuum, SAW, Pirani, IDT.

SHORT SUMMARY

Pressure is a key parameter for a large number of industrial processes. The vacuum industry relies on accurate pressure measurement and control. Designing a single device being able to sense from very high vacuum to atmospheric pressure is a challenge to an interdisciplinary research community, leading to the development of pressure sensors using different operating principles.

An attempt to design a compact wireless sensor handling pressures between 10^{-4} Pa and 10^{5} Pa is presented. The core of this device consists of a 1 cm^3 polymer cube crossed in its center by a 500 µm diameter cylindrical microchannel. The sensing element is a Surface Acoustic Wave Interdigital Transducer created on a piezoelectric substrate and is based on the SAW Pirani principle. The sensing element is located inside the crossing channel. The heating and interrogating elements are dipole antennas screen-printed on the bulk of the cube.

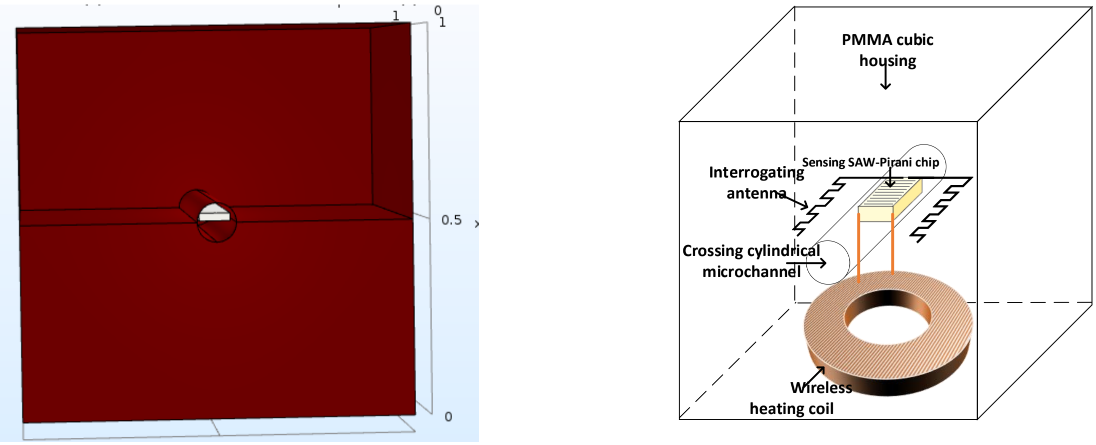

Figure 1: Geometry of the sensor simulated and structure of the sensor

A thermal analysis of the behavior of the sensor at low pressure is presented. The behavior at high vacuum and near atmospheric pressure is analyzed to justify the dimensioning of the sensor aiming to optimize its sensitivity in both regions. Indeed, the efficiency of the sensor is directly linked to regime of the gas being sensed. The regime of the gas is determined by the value of the Knudsen number:

$$Kn = \frac{\lambda}{d}$$

Where λ denotes the mean free path of the gas molecule and d a characteristic dimension of the chamber where the gas is located. The optimum regimes for the Pirani effect are the molecular regime and i.e. a Knudsen number between 0,001 and 10. The Knudsen number should be kept in this interval as much as possible through the sensing range. The thermal conductivity of the gas should also have measurable values.

Pressure	Mean free path (m)	Thermal conductivity (W/m/K)
0.0001 Pa	11,7842	6,91e-8
0,0003 Pa	3,9281	2,07e-7
0,0005 Pa	2,3568	3,45e-7
0,001 Pa	1,1784	6,91e-7

Table 1: Mean free path and thermal conductivity of Nitrogen at high vacuum

Pressure	Mean free path	Thermal conductivity
10 000 Pa	1,18e-7	0,0163
50 000 Pa	2,4e-8	0,0232
100 000 Pa	1,2e-8	0,0245
101 325 Pa	1,2e-8	0,0246
200 000 Pa	6e-9	0,0252

Table 2: Thermal conductivity and mean free path of Nitrogen near atmospheric pressure

The objective is to achieve a maximum steady state temperature difference between the pressures and simulation with the software COMSOL is used to optimize the dimensions of the chip and channel.

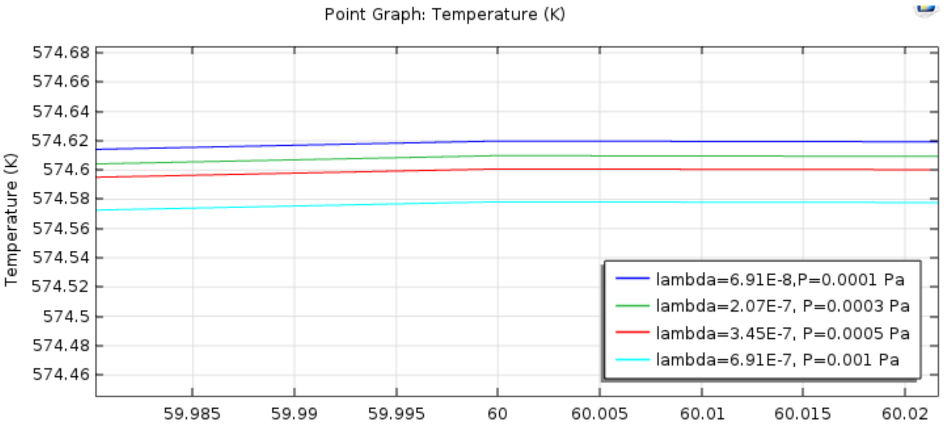

Figure 2: Temperature of the sensor at 60 s at high vacuum

The temperature difference between the pressures is around 0.1 K which corresponds to the sensitivity of wireless SAW devices currently available in the market.

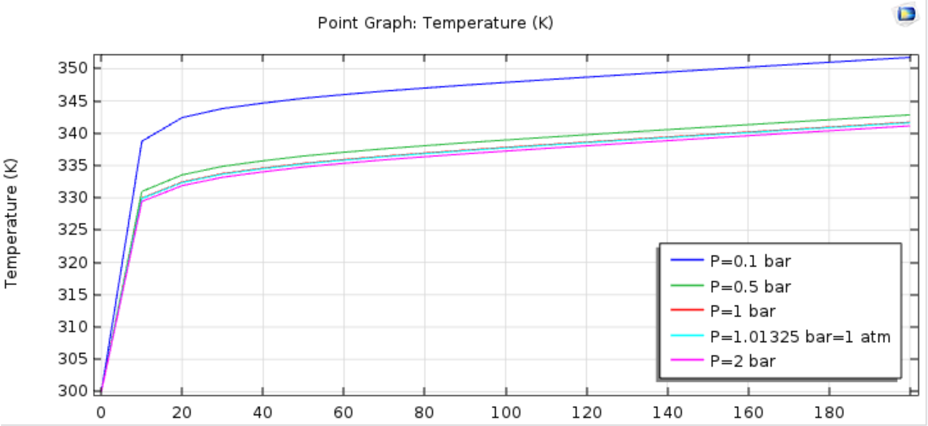

Figure 3: Thermal response of the sensor near atmospheric pressure

The temperature difference near atmospheric pressure is higher and more easily measurable.

Simulation shows that a single device sensing high vacuum to atmospheric pressure is feasible. However, a more accurate thermal conductivity values are needed. In the simulation the sensor is not physically connected to the bulk which is not realizable in practice. Losses due to solid conduction will be introduced in the simulation. This simulation allows to define the main dimensions of the new SAW-Pirani sensor. Further work will focus on the manufacturing of a prototype.

Acknowledgements

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