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DESIGN, DEVELOPMENT AND VALIDATION OF A MICRO-PIRANI PRESSURE SENSOR FOR MICRO AND MACRO SCALE APPLICATIONS

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Pirani gauge, heat loss, transmission system, micro scale

ABSTRACT

Pirani pressure sensors rely on the heat transfer that occurs when a hot wire is surrounded by a gas. The heat taken from the wire by the surrounding gas is proportional to the number of molecules of gas that impact the wire and therefore to the pressure. When the wire is connected to a circuit, we can correlate the pressure of the surrounding gas with the wire temperature variation, its resistance and with that to a voltage that can be measured. The project is dedicated to model and simulate, develop and characterize experimentally a micro Pirani sensor in micro scale. The sensor should act independently from the gas and not influence the ongoing processes (heat transfer) in the media where it is placed. A literature review has been performed and is still in progress. Several general equations and models for the Pirani pressure sensor have been found as well as the corresponding assumptions. The objective of these equations is to obtain the value of pressure from the measured voltage.

Literature review and physical model

Recently, new prototypes and concepts of micro structured vacuum sensors have been developed using the Microelectromechanical systems (MEMS) technologies. In this field, micro Pirani sensors based on resistive or thermoelectric detection principle have attracted the designers due to their simple structure. A classical Pirani gauge consists of a metal filament (usually in platinum, nickel or tungsten) suspended in a tube connected to the system in which the vacuum level has to be measured. The equilibrium temperature of the wire depends on the heat transfer, between the wire and the surrounding gas, which is strongly influenced by the gas pressure value.

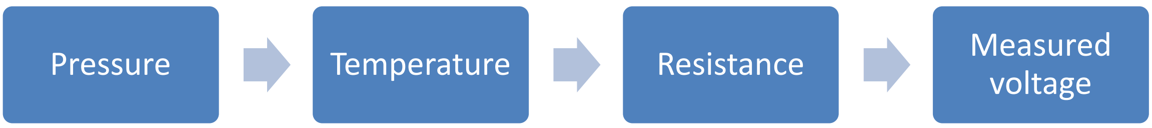

Figure 1: Transmission of information

The relationship between the wire electrical resistance and the measured voltage is the well-known Ohm law:

$$U = RI \tag{1}$$

where U denotes the voltage measured at the Pirani gauge, R its resistance and I the corresponding current. The relationship between temperature and resistance is:

$$R = R_0[1 + \alpha_0(T - T_0)] \tag{2}$$

where R_0 denotes the resistance of the Pirani gauge at the reference temperature T_0, $\propto_0$ is the gauge´s thermal coefficient of resistance (TCR) which depends on the material of the gauge, and R_S denotes the resistance of the gauge at temperature T.In a classical Pirani sensor the heat exchanged by the heated wire in steady state conditions with the surround can be expressed as the sum of the heat exchanged between the wire and the gas (G_{gas}), the heat loss by conduction through the solid thermal bridges existing between the wire and the sink (G_{solid}) and the heat losses due to radiation (G_{rad}) which is generally negligible if compared to G_{solid}:

$$P(p) = (T - T_0)(G_{rad} + G_{solid} + G_{gas}(p)) = RI^2 \tag{3}$$

where P denotes the Joule power which corresponds to the heat loss of the gauge, p is the pressure, T is the gauge temperature, In [1] and [2], radiation is neglected because of the low temperature whereas in [3] it is not neglected. Convection inside the gas is never considered due to the small size of the device. Moreover, $G_{gas}(p)$ is not always defined in the same way.

The Pressure range is interesting to work on. The overall pressure range in the articles reviewed is from 10^{-6} Torr to atmospheric pressure in a very disparate way. No gauge covers this whole range. The covered range depends on the gauge´s dimensions. According to [4], the gauge should have the largest surface area for low pressures and the smallest gap between the gauge and its substrate for high pressures.

To monitor microscale processes a response time of the sensor of less than 1 ms is needed but the smallest response time available so far in literature is 10 ms in [5].The transmission system of the gauge to the user should be improved. To do so, near field communication, optical transmission and wireless communication will be explored.

Microelectronic components already exist and manufacturing technologies are well known. Suitable components and their layout in a circuit should be done to reach the desired pressure range, precision and response time.

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