MICRO CORIOLIS GAS DENSITY SENSOR

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ABSTRACT

In this paper we report on gas density measurements using a micro Coriolis sensor. The technology to fabricate the sensor is based on surface channel technology.

The measurement tube is freely suspended and has a wall thickness of only 1 micron. This renders the sensor extremely sensitive to changes in medium mass and therefore density.

The average stability of the density measurement is 0.01 kg/m^3. Temperature dependency is 0.02 kg/m^3/°C. Pressure dependency is approximately 2 kg/m^3/bar. Accuracy of several common gases is on average better than 0.2 kg/m^3.

KEYWORDS

Gas, Density, Coriolis sensor

INTRODUCTION

Gas density sensors are interesting for quality control and real time gas composition measurement [1]. Here we report on gas density measurements using a micro Coriolis sensor as reported in [2]. A Scanning Electron Microscopy (SEM) picture of the sensing tube is given in figure 1.

SENSOR DESCRIPTION

Novelty

The sensor has an extremely thin wall of only 1 micron, which renders the sensor extremely sensitive to changes in medium mass and therefore density. The ratio of the mass of the medium inside the tube and the mass of the tube is at least 10-20 times larger than in conventional stainless steel tubes. As compared to current MEMS Coriolis density sensors this ratio is more than 2 times larger than current MEMS Coriolis density sensors [3].

Chip

The sensor chip is based on the technology developed by Dijkstra et al [4]. With this technology channels at the surface of a silicon substrate can be fabricated. In figure 1 a SEM picture is given of the tube. The free hanging tube has an inner diameter of approximately 50 μm and a wall thickness of approximately 1 μm. The tube wall is LPCVD silicon rich silicon nitride. The electrodes are gold.

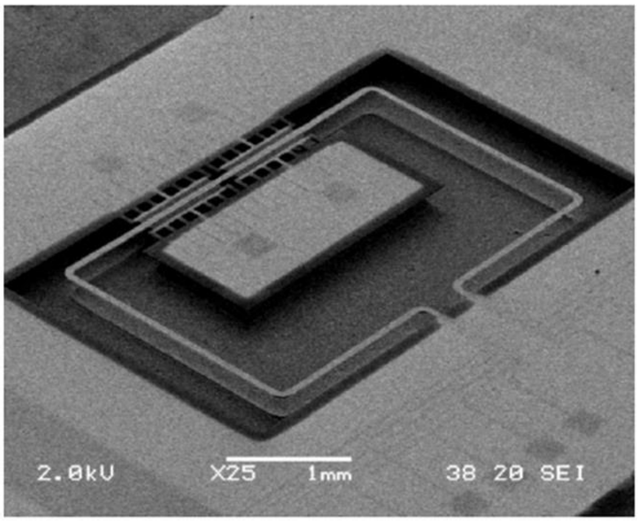

Figure 1: Scanning Electron Microscopy photo of the sensing tube. Sensing structures are shown at the top left of the figure.

Electric and fluidic interface

Actuation of the tube is performed using Lorentz force. The detection part uses electrostatic comb structures [2]. Here displacement of the tube causes a change in capacitance that is transformed into a voltage change. This is detected by a digital signal processor (DSP) via several analog to digital (ADCs) and chip actuation is performed using digital to analog converters (DACs). The combination of the above components and the sensor renders a closed control loop that locks the actuation frequency to the tube resonance frequency. This type of control loop is commonly called a phase locked loop (PLL). The chip is interfaced to a charge amplifier by wirebonding to a printed circuit board (PCB).

The chip is interfaced to the outside world using two 1/16” stainless steel tubes. The seal material between the stainless steel tubes and the chip is Kalrez.

EXPERIMENTAL

Before the density experiments helium (He) pressure and leak tests were performed. The sensor is He tight (< 2×10^{-9} mbar.l/s) up to 20 bar.

To check the stability of the sensor the density of nitrogen gas was measured. This was done in the setup presented in figure 2. The sensor was flushed with nitrogen for 10 minutes. To prevent gas diffusion to and from the sensor valves before and after the sensor were closed and the density was logged.

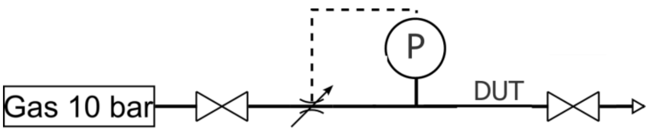

Figure 2: Schematic view of the setup. DUT is defined as device under test. Gas pressure is delivered using a mechanical pressure controller at 10 bara. A pressure meter (P) is used to electronically control the pressure using an electromagnetic valve.

In two separate experiments temperature and pressure dependency of the sensor was measured. The temperature dependency was measured in a climate chamber (Vötch VC4018). The pressure dependency was measured using the setup given in figure 2.

The density measurement was calibrated on nitrogen and water at zero flow, atmospheric pressure and room temperature.

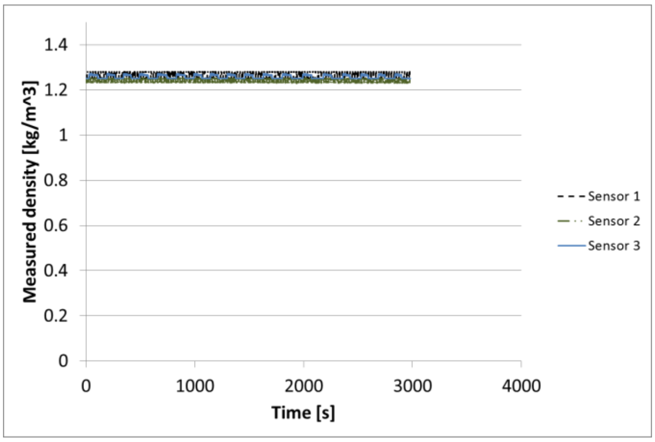

Figure 3. Measured density of nitrogen at room temperature as a function of time.

RESULTS

The result of measurements with three different sensors during 50 minutes is given in figure 3. The stability is approximately 0.01 kg/m^3.

Table 1. Measured density versus reference density

	Reference density [kg/m^3]	measured density [kg/m^3] sensor 1	measure d density [kg/m^3] sensor 2	measure d density [kg/m^3] sensor 3	average deviation [kg/m^3]
N2	1.25	1.25	1.25	1.25	0.00
Ar	1.79	1.76	1.56	1.78	-0.08
CO2	1.98	1.90	1.80	1.91	-0.10
He	0.18	0.20	0.24	0.36	0.09

Temperature dependency is 0.02 $kg/m^3/°C$. Pressure dependency is approximately 2 $kg/m^3/bar$. Especially the measured pressure dependency is too high for practical use in gas density measurement. Therefore, pressure sensors will be included to compensate the pressure effect.

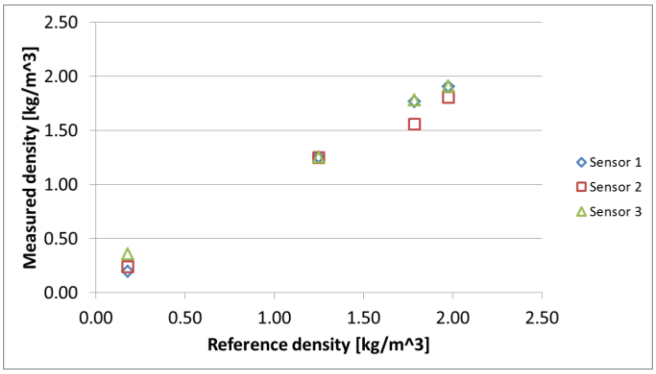

Figure 4. Measured density of helium, nitrogen, argon and carbon dioxide as a function of reference density.

The sensors were tested for several common gases (helium, nitrogen, argon and carbon dioxide). The result of this measurement is shown in figure 4 and 5 and in table 1. Interestingly it shows excellent behavior (i.e. within the measured stability) at nitrogen, however, not with the other gases. This is likely caused by calibration. Since calibration is only done for one gas and one liquid and liquid has an approximately 1000 times higher density than gas, minute errors in this calibration cause considerable errors in density measurement for media other than in this case nitrogen and water.

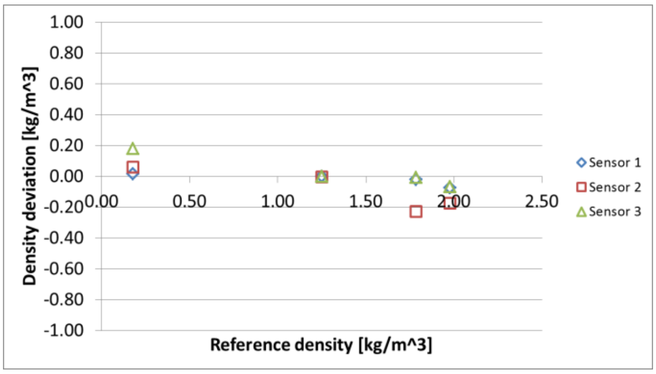

Figure 5. Measured deviation in density of helium, nitrogen, argon and carbon dioxide as a function of reference density.

CONCLUSION

To conclude we presented experiments on gas density measurements using a micro Coriolis sensor. The sensor element is freely suspended and is made of silicon nitride. This makes the sensor chemically resistant to most gases. We tested this chip with several common gases and found predictable behavior. The average stability of the density measurement is 0.01 kg/m^3. Temperature dependency is 0.02 kg/m^3/°C. Pressure dependency is approximately 2 kg/m^3/bar. The current calibration method needs improvement since average errors up to 0.2 kg/m^3 are measured between several common gases.

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