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Abstract

Indoor Air Quality CO_2 Thermally Modulated SMR Sensor †

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Abstract: This paper reports on a CO_2 solidly mounted resonator (SMR)-based sensor with an integrated heater. The SMR device is CMOS compatible and operates at a resonant frequency of 2 GHz. To increase the sensitivity and selectivity, the SMR devices were functionalized with a 20 µm CO_2 sensitive layer. Two SMR sensors were employed in a differential configuration; one sensor was uncoated and used as a reference and the other was coated and used as a sensing device. The frequency shift of ~8 kHz/% CO_2 in dry air was observed after temperature and humidity compensation; demonstrating its potential application in indoor air quality (IAQ) monitoring.

Keywords: solidly mounted resonators (SMR); CO_2 detection; indoor air quality (IAQ); gas sensors; volatile organic compounds (VOCs)

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1. Introduction

The impact of air pollution on human health is causing a systemic problem worldwide. In 2016, seven million deaths were reportedly attributed to poor air quality [1] and it is estimated that the cost to the UK will be £5.3 billion by 2035. The ability to monitor air quality in real time is necessary in order to provide fast responses, essential to alerting people to hazards and to take appropriate measures. The European Union has set annual average target values [2] for air pollution. EU countries must monitor and produce annual reports adhering to the air quality regulations. Moreover, workplaces are also required to have sensors to monitor air quality, following health and safety regulations [3].

The goal of this work is to explore the application of solidly mounted resonator (SMR)-based devices for the detection of CO_2. The low-cost, MEMS-based sensors employ selective chemical coatings aiming to achieve better sensitivity and selectivity compared to the CO_2 sensors currently available on the market. In addition, the SMR devices used in this paper have integrated micro-heaters allowing for improved thermal stability of sensors. With greater sensitivity and lower costs, the end goal is to bring a novel air quality sensor to the market.

2. Materials and Methods

The SMR device used in this work is shown in Figure 1. The overall device size is 1.0 mm × 2.5 mm, whilst the size of the gas sensing area is 500 µm × 351 µm. The sensors were fabricated at SilTerra (Malaysia) using a combined CMOS-MEMS 180 nm process. After fabrication, the SMR devices were coated with thin CO_2-sensitive polymers developed by Sorex Sensors Ltd., Cambridge, UK. The principal detection method using SMR devices is based on a differential configuration, with one sensor used as the reference and the other one used as a sensing device. Both devices are used in the Pierce oscillator configuration followed by an RF amplifier. The amplified signals were fed to a mixer circuit, and the frequency difference between the two oscillators was passed to a microcontroller as described in [4].

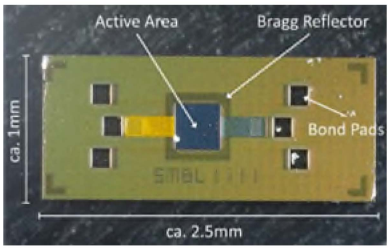
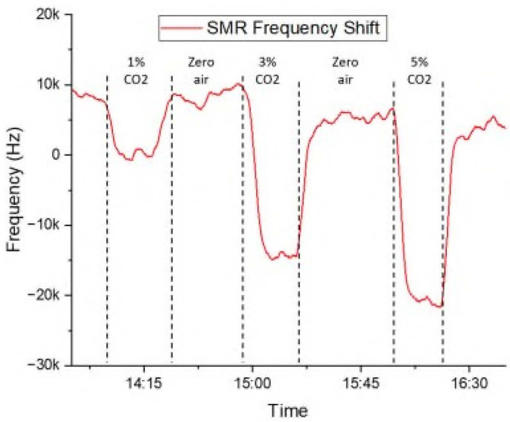


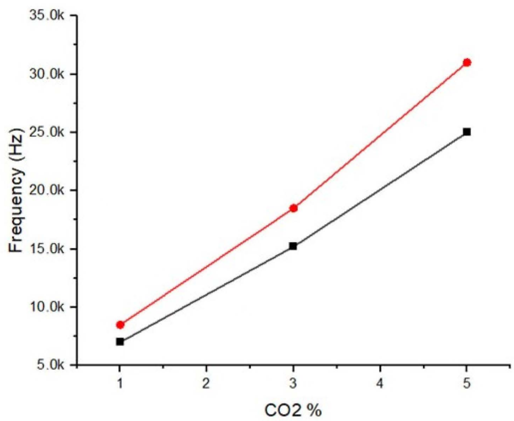
Figure 1. Photograph of an uncoated SMR device with the active area above a Bragg reflector [4].

3. Results

The sensors and interface circuitry were placed in a commercial Memmert oven, and the temperature ranged from 30 to 70 °C to find the temperature and humidity coefficient factor (TCF, HCF) of the sensor system. From the experiments, the TCF was determined to be −310 ppm/°C and the HCF was +235 ppm/(g/m^3). Figure 2a shows the response of the differential configuration to three consecutive exposures to 1%, 3%, and 5% CO_2 in dry air. The frequency shift for each gas concentration is found to be 7–8 kHz, 15–19 kHz, and 25–30 kHz, respectively. During these experiments the oven temperature was kept at 40 °C while the sensor micro-heater was set to 70 °C. Figure 2b shows the extracted sensor response with CO_2 concentration in two experiments repeated days apart.



(**a**)



(**b**)

Figure 2. (**a**) Responses to 1%, 3%, and 5% CO_2 in dry air. (**b**) Repeatability of the device (two experiments a few days apart).

4. Discussion and Conclusions

In this paper, we report on the design and development of a SMR-based CO_2 sensor with integrated micro-heater. Initial results are promising and indicate a sensitivity of ~8 kHz/1% CO_2. Further tests are underway to further explore the benefits of an integrated micro-heater on sensor sensitivity, selectivity and stability in humid air. The response time of coatings with different thicknesses is being explored as well as more advanced interface circuitry.

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