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Cost-effective Indoor Air Quality Colorimetric CO_2 sensor.

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Summary:

A colorimetry CO_2 ppm level sensor has been developed. Based on an optimized water-based ink, the sensor covers the range of 250 to 1500 ppm, is not affected by common indoor pollutants (NO_2, CO, CH_2O) and do not show signs of degradation after a week of operation. A calibration method has been proposed to dampen the effects of humidity on sensor prediction. Find out more at the conference.

Keywords: Colorimetry, CO_2, Indoors Air Quality, Optical sensor, Cost-effective

Background, Motivation an Objective.

Gaseous CO_2 real time determination has emerged as an imperative need after the current pandemic situation, particularly to monitoring indoor air quality. Over the past years, CO_2 was promoted as a proxy to other co-exhalated airborne microorganism. Indoor CO_2 levels are expected to remain around 400 parts per million (ppm), and no more than 700 ppm above that. Otherwise, a deficiency in fresh air circulation would be present, indicating potential poor air quality for the occupants around.

Sensors based on dye colorimetry are a potential resource for the development of compact cost-effective gas detectors. Colorimetry inks are inexpensive and easy integrate into commercial miniaturized colour readout systems [1], as well as smartphones [2]. To the best of our knowledge, state-of-the-art colorimetric sensors usually fail at measuring concentrations below 5000 ppm of CO_2 [3]. For example, A.Davey et al. developed an amine - ZIF-8 sensor exhibiting a colour shift at 700 ppm of CO_2 [4]; D. Zhao et al. managed to pick up signal from 280 to 1345 ppm but without reaching equilibrium, being impossible to link to a specific concentration [5] and R. Dansby-Sparks et al. achieved a limit of detection of 80 ppm but was not studied under real conditions (Relative humidity, gas interferents) [6].

In our work, we developed a water based colorimetric ink tunned to monitor CO_2 in the range of 250 to 1500 ppm. The ink formulation is based on an amine and a pH indicator. The detection of gaseous CO_2 is achieved by a nucleophilic attack on CO_2 by a primary amine to produce a shift in the acidity level of the ink, thus changing its color. The ink is printed and integrated into a commercial MAX30105 chip which encloses three LEDs and a photodetector. The transmitted and reflected light from the ink after CO_2 exposure is measured by the photodetector, which transduces it into a signal.

Results

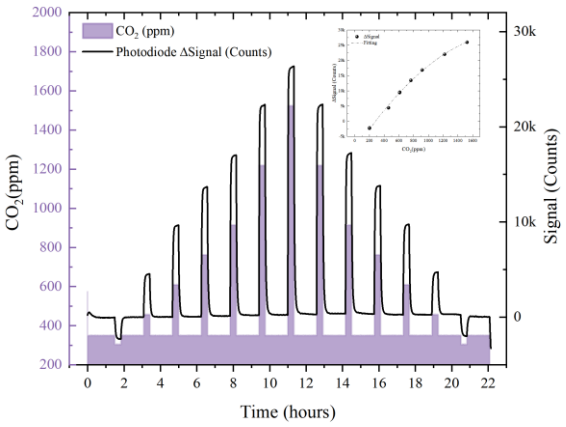

Fig. 1. Transient measurement signal at different CO_2 concentration and constant humidity (50%). Increment of signal vs CO_2 at insert.

The formulation of the ink was adjusted to maximize the detection of CO_2. We characterized the influence of the reagents in both, dry and moisture conditions (50% Relative Humidity; RH). With the adjusted formulation, our sensor was exposed to increments of CO_2 from 250 ppm to 1500 ppm (Figure 1.). The response shows a complete reversible behavior with a non-linear relationship with CO_2 concentration. The baseline exhibits no drift, demonstrating good stability over the 22-hours experiment. To characterize the interaction with humidity, we exposed our colorimetry sensor to 600 ppm

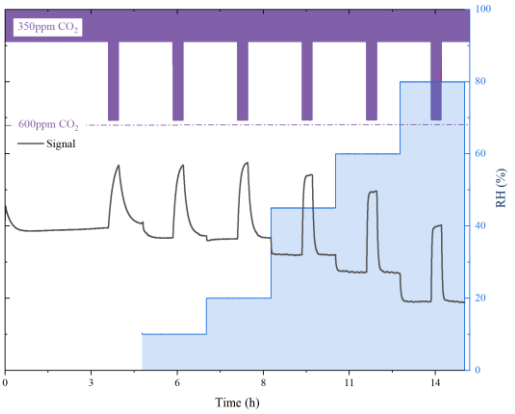

Fig. 2. Sensor signal to 600 ppm pulses of CO_2 under a scale up of humidity (0-80% RH) (Top). Detailed response and slope during CO_2 pulses (Below).

CO_2 pulses at different RH from 0 to 80% (Figure 2). We observed there was not important influence in the response of the sensor as the increment in signal remains close for all % RH. The shape of the pulse reveals that the velocity of the CO_2 – amine reaction is enhanced in presence of moisture. The baseline color is obviously affected by the humidity, but the response towards CO_2 is practically the same (Figure 2) . We decided to characterize this behavior by keeping constant a flow of 350 ppm and varying moisture from 0 to 70% RH (Figure 3). The signal decreased with the increasing amount of RH with a quadratic behavior. We associated a real time humidity sensor to damp its effect. To establish a calibration method, we exposed our CO_2 sensor, coupled to the humidity sensor, to a variety set of CO_2/humidity conditions. Figure 4 depicts the predicted CO_2 concentrations of our colorimetric sensor. The accuracy associated to each change does not exceed the 10%.

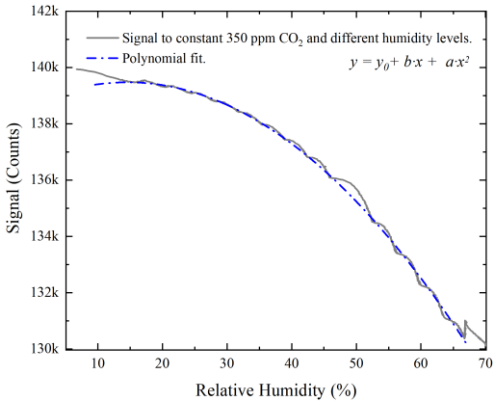

Fig. 3 Signal to constant 350 ppm CO_2 and different humidity levels.

Next, we studied the cross interference towards CO, CH_2O and NO_2, finding no signs of influences. Finally, we realized a 1-week experiment subjecting the sample to a constant flow of 350 ppm and 50% RH and periodic pulses that rise to the limit recommended by the authorities of 1200 ppm. The response remained

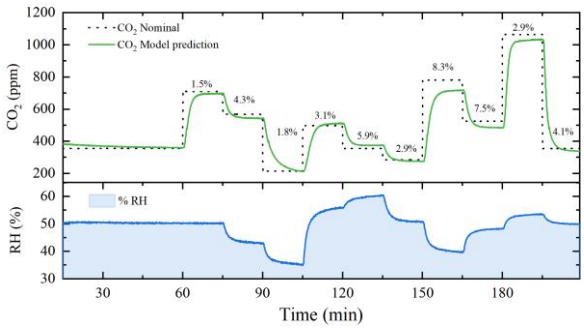

Fig. 4.CO_2 predicted by our colorimetry sensor under random humidity conditions.

practically constant throughout the seven days.

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