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A Gas Sensor Device for Oxygen and Carbon Dioxide Detection †

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Abstract: Sensors for monitoring oxygen and carbon dioxide are crucial as investigational devices in many different research fields, including environmental, biomedical and industrial. They must be easily configurable, fast responding, and with good reproducibility and sensitivity. The state of art reports different sensing and transducing strategies: electrochemical, optical, conductometric etc., based on specific chemically interactive materials. In this work, a multisensor system based on electrochemical sensors acting via a liquid medium and controlled by a dedicated low-noise electronic interface is equipped with an elaboration unit able in extracting/storing a committed model for oxygen and carbon dioxide detection.

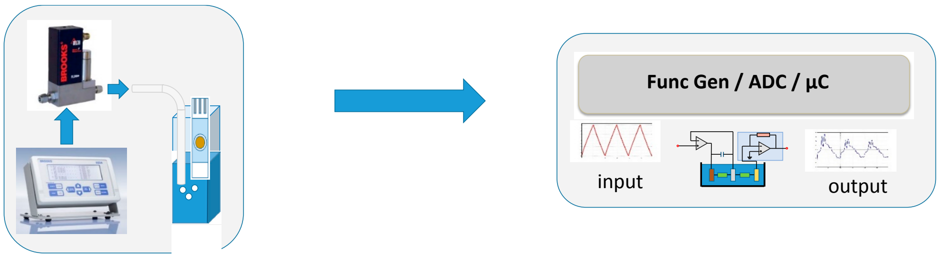
Keywords: OSAS; gas sensor array; Quartz Micro Balance; COPD

1. Introduction

Continuous monitoring of Oxygen and Carbon dioxide concentration is crucial for many different application fields, ranging from bio-medical studies to food-packaging processes and environmental monitoring. This is due to the role of these gases in important biochemical reactions [1] and more in general in the air quality determination [2]. Different application fields require different concentration ranges, but on-field and on-line applicability is of course mandatory. The state of the art is represented by electrochemical, optical and conductometric approaches [3–6], with excellent pros and not negligible cons.

2. Materials and Methods

Herein, we describe a calibrated device for oxygen and carbon dioxide measurements. The system is based on voltammetric sensors with a low noise electronic interface. The sensors are lodged in a vial containing a physical solution. The solution provides an effective interaction with the gases bubbled into the liquids. The change of liquid composition are detected by the device composed of three electrodes (1) the working electrode (gold); (2) the counter electrode (platinum); (3) the reference electrode (silver/silver dioxide). The output signals are obtained applying an input triangular waveform at a frequency of 10 mHz and with voltage values ranging from between −1 V and 1 V. Yet, the voltage can be modulated (with respect to both amplitude and frequency) acting on the internal waveform generator parameters. The output signal is obtained with a sampling time of 1 s, collecting 100 samples of the output current, treated as a single 'fingerprint' composed of a virtual array of 100 sensors. The calibration sampling protocol has been designed using a mass-flow controller able to deliver specific concentration levels of O_2 and CO_2 in the range of interest. The sensor system has been calibrated considering concentrations ranging from 5% to 50% (steps of 5%) of oxygen and from 2% to 20% (steps of 2%) of carbon dioxide both in a N_2 carrier gas. The model has been built using Partial Least Square Discriminant Analysis (PLS-DA).



Measured mixtures (N_2 – CO_2)
2% CO_2 – 98% N_2
3% CO_2 – 97% N_2
4% CO_2 – 96% N_2
5% CO_2 – 95% N_2
10% CO_2 – 90% N_2
15% CO_2 – 85% N_2
20% CO_2 - 80% N_2

Measured mixtures (N_2 – O_2)
5% O_2 – 95% N_2
10% O_2 – 90% N_2
15% O_2 – 85% N_2
20% O_2 – 80% N_2
25% O_2 – 75% N_2
30% O_2 – 70% N_2
35% O_2 – 65% N_2
40% O_2 – 60% N_2
50% O_2 – 50% N_2

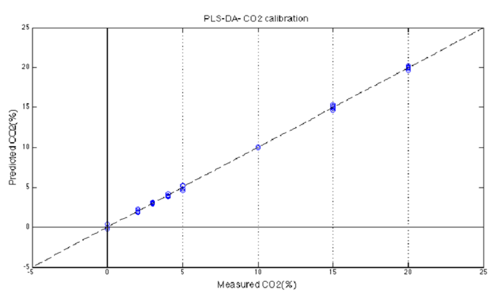
Measure time	30 s
Flow	100 sccm
Cycle # per session	5
Input frequency (Period)	10 mHz (T=100s)
Input Amplitude range	-1 V / 1 V
Electrode's materials	WE: Gold CE: Platinum RE: Silver

Figure 1. Sampling protocol. Calibration parameters and device settings.

3. Results

The predictive model shows a good reproducibility in terms of measurements and a reduced root mean square error in validation. The Root Mean Square Errors in cross validation are around 2% for both O_2 and CO_2, which does represent a promising performance both for IAQ (Indoor Air Quality) and breath analysis applications. Moreover, this sensor could be effective in several fields of applications (e.g., Bio-Medical, industrial, wearable), and in particular can also provide a quick estimation of metabolism parameters for discriminating glycolytic vs. oxidizing glucose metabolism. Additionally, as the tool can record in real-time a huge number of observations, it could provide data required for calculating the Ljapunov functions of non-equilibrium processes, like those occurring during metabolism in living systems [7] and pathological conditions, like cancer [8].

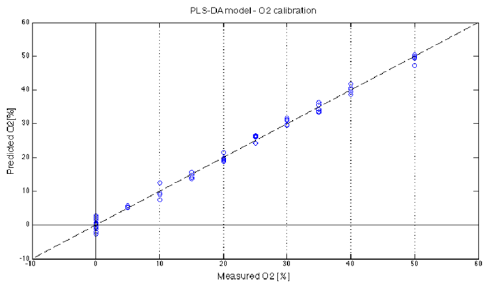
Predicted vs measured



model performance

Model performance	
RMSEC	0,32%
RMSECV	1,97%

Figure 2. *Cont.*



Model performance	
RMSEC	1,25%
RMSECV	2,16%

Figure 2. Data analysis results. Fingerprints obtained by different concentration of O_2 and CO_2 are processed by PLS-DA model. RMSEC and RMSECV are reported.

4. Discussions

Results herein reported evidence how the sensor is reliable and how it can be useful for many different fields of applications. Besides, each application asks for a specific release with different specifications in terms of size, power consumption, and user interface and this appears rather possible by the here proposed sensor system.

Conflicts of Interest: The authors declare no conflict of interest.

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