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Abstract

Development and Deployment of Portable Sensor Platforms Based on a Micro-Electro-Mechanical-System Chemoresistive Gas Sensor Array for Outdoor Air Quality Monitoring †

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Abstract: Nowadays, there is a growing demand for a well-distributed sensor network to monitor air quality which can aid policymakers in making decisions. This has led to an increase in the R&D of cost-effective and energy-efficient sensing solutions. In this study, sensing platforms composed of MEMS chemoresistive gas sensors were developed and deployed in two Italian cities for the detection of pollutants. Over three years of measurements, the sensors have proven to be reliable in detecting CO, NO_2 and O_3 with high accuracy compared to data collected by local environmental protection agencies, paving the way for their potential validation and future adoption.

Keywords: environmental monitoring; chemoresistive gas sensors; embedded systems

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1. Introduction

Despite the EU's efforts to reduce outdoor air pollutants, some toxic gases, such as NO_2 and O_3, still exceed the recommended limits, resulting in high economic costs and premature deaths. To tackle this problem, the European Commission's resolution 'Clean Air for All' calls for the development of low-cost, portable, multi-sensory intelligent air quality monitoring systems. These new devices need to be high performing but at the same time low cost and portable in order to be employed alongside the currently used high-cost, certified monitoring tools of the environmental protection agencies (EPAs) and remote sensing to obtain a well-distributed sensing network that can support the policymaker and public bodies in their decision for contrasting the emission and spreading of the pollutants. Here, we present the data collected over 3 years regarding the deployment of sensor platforms developed at the Bruno Kessler Foundation (FBK), based on arrays of micro-electro-mechanical-system (MEMS) chemoresistive gas sensors.

2. Materials and Methods

The arrays of MEMS chemoresistive gas sensors were composed of different nanostructured Metal OXide (MOX) semiconductors, synthesized through the sol–gel method. The nanostructured MOX semiconductors were deposited through screen printing onto low-power-consumption micro-hotplates, obtained through silicon microfabrication processes, as described in [1]. A preliminary screening of the most suitable MOX semiconductors to be deployed for in-field calibration and tests was carried out in a custom-made gas test bench, equipped with gas cylinders with certified concentrations, mass flow controllers, a sealed chamber hosting the sensors and a suitable electronic board for signal read-outs [2]. The final sensor platforms (Figure 1a) were composed of (i) MEMS chemoresistive gas sensors; (ii) a custom-made electronic board for sensor signal read-outs; (iii) Raspberry Pi0 for communication and data transmission; (iv) a pump for air recirculation; and (v) a custom-made enclosure. In total, seven sensor platforms were deployed and tested, two in Trento (from 2019 to date) and five in Terni (from 2021 to date). Certified data of the EPA were used as a gold standard for the calibration of FBK devices, obtained through the development of a deep neural network (DNN)-trained model.

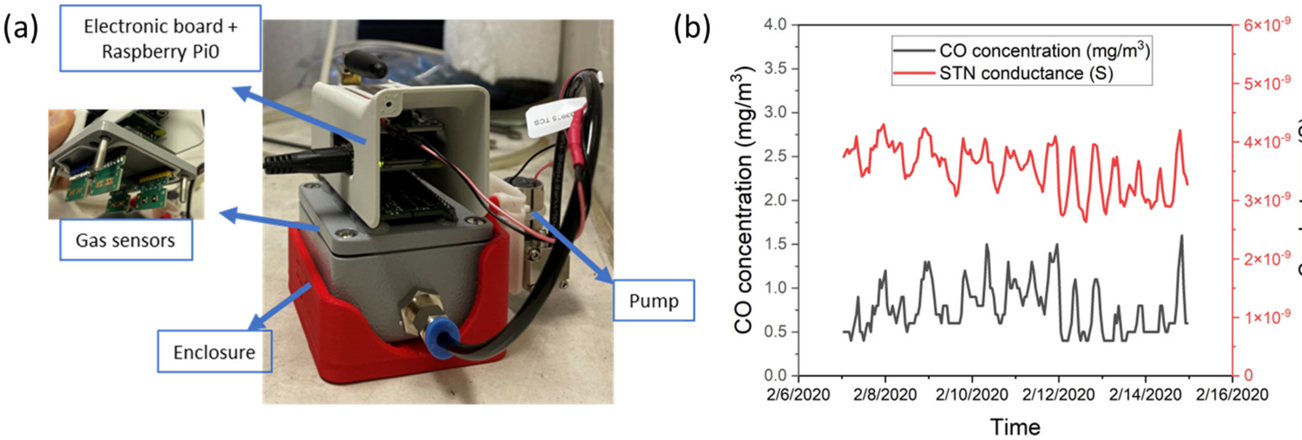

Figure 1. (**a**) Prototype of final sensor platform; (**b**) comparison between SnTiNbOx (STN) electrical conductance (orange line) and the real concentration of CO (EPA monitored, blue line), from 6 to 16 February 2020.

3. Discussion

The preliminary measurement campaign, performed using the custom-made gas test bench at FBK, defined the most suitable sensing materials to be used in the final gas sensor platforms [2]: ZnO for O_3 detection, SnTiNbOx solid solution for CO detection and three different sensing materials ($LaFeO_3$, $SmFeO_3$ and WO_3) for NO_2 monitoring. During the deployment of the sensor platforms (Che Aria! and TernAria projects), sensor raw data collected (Figure 1b) were divided into three datasets for training, validation, and testing the DNN model used for device calibration. The model was optimized by minimizing the mean square error (MSE). The R-square (R^2) was used to compare the predicted concentration by the MEMS chemoresistive gas sensors with the actual concentration of pollutants detected by EPA tools during validation. O_3 (87.2%) and CO (80.5%) had very good R^2, but NO_2 (R^2 = 70.4%) needs further improvement in model calibration.

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

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