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Gauging indoor air quality with inexpensive gas sensing technologies

Alvaro Ortiz Perez[a], Benedikt Bierer[a], Ponkanok Eaksen[a], Jürgen Wöllenstein[a], Stefan Palzer[a,]*

[a]*Department of Microsystems Engineering – IMTEK, Laboratory for Gas Sensors, University of Freiburg, Georges-Köhler-Allee 102, 79110 Freiburg, Germany*

Abstract

Here we present a sensor system that is capable of detecting trace gases related to indoor air quality and well-being inside. Using a combination of optical and solid-state technologies we aim at detecting the key pollutants in the indoor environment. The sensing system is equipped with wireless technology such that the data obtained may be transmitted and made available to cloud-based applications. The information may then be used to understanding the exposures of individuals to these pollutants, characterizing the levels that trigger health effects, and balancing the risk from air pollutants with the benefits of improved energy management and insulation.

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Keywords: indoor air quality, health and well-being, photoacoustics, metal oxide gas sensing

1. Introduction

Today, one of the most dangerous environmental problems is air pollution, which causes a multitude of adverse health effects. It is responsible for about 600.000 deaths in Europe [1] and many more illnesses. Because people in developed societies spend the vast majority (~90%) of their time indoors they are subject to a range of associated risks to their health. Not only do outdoor pollutants penetrate their homes but a large number of building materials emit a wide range of air pollutants into the indoor environment, as do the animals and pests that share these buildings.

* Corresponding author. Tel.: +49 (0) 761/ 203 - 67583
E-mail address: stefan.palzer@imtek.uni-freiburg.de

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Domestic activities, such as cooking and cleaning additionally contribute to household pollutants, as do a wide range of commercial and industrial emissions in the workplace. Finally, houses have become better insulated to conserve energy and thereby decreasing the air exchange causing accumulation of pollutants in the house. This issue is becoming more important because the insulation of both residential and commercial buildings has accelerated in recent years due to national and international climate programs aimed at reducing the total energy consumption. This trend is set to continue in the years to come as energy costs continue to soar and efforts to reduce carbon dioxide (CO_2) emissions are intensified.

In this scenario the control and gauging of indoor air quality (IAQ) becomes paramount for both the health and well-being of people inside. The parameters governing well-being, health and safety of inhabitants are temperature, relative humidity, as well as the concentrations of carbon dioxide (CO_2), so-called volatile organic compounds (VOCs), carbon monoxide (CO), and nitrogen dioxide (NO_2). The latter two gases are highly relevant to prevent the loss of life due to accidents and usage related to gas appliances.

2. Experimental

2.1. Setup

We present a sensor node that is connected to the internet via a z-wave communication protocol in combination with a gateway. To detect the gases we use a combination of a photoacoustic approach and metal oxide based gas sensors. The photoacoustic approach leans on a non-dispersive infrared spectroscopy (NDIR) setup. Unlike commonly employed schemes, we use a mid-infrared light emitting diode (MID-IR LED) as light source and a hermetically sealed, CO_2-filled miniature cavity with a microphone as light detector. By modulating the intensity directed at the custom-built, photoacoustic detector, we excite sound waves at the modulation frequency in the latter. These can be detected using the commercially available MEMS microphone and the amplitude is determined using the Goertzel algorithm, after a signal amplifier stage. Because the sound wave amplitude is proportional to the light intensity, this approach provides means to measure the light intensity. Most notably, the detector act as a filter, since only photons resonant to a CO_2 absorption line contribute to the generated signal. The system can detect CO_2 levels in a wide range from 400 ppm – 5,000 ppm highly selectively.

To detect VOCs we use several low-power consuming metal oxide detectors which we operate in a steady-state thermal modulation scheme. Figure 1 (a) shows a scanning electron microscope image of the array chip we use. It consists of three individually controllable micro hotplate devices, each of which is equipped with a Ta/Pt heater and an interdigitated electrode structure. Using an inkjet printing approach we deposit different metal oxides on top of each hotplate. The combination of temperature modulation schemes and the varying gas sensing properties of the metal oxide layers allow for an increase in selectivity.

Commercially available temperature, humidity and pressure sensors complement the information extracted about the state of indoor climate and also allow for providing a well-being indication.

The modular system may be adapted to various situations and is able to detect dangerous concentrations of CO and NO_2. It can cover important aspects for an optimal IAQ and communicate with cloud-based platforms to enable user interaction and intelligent air quality control. This may be used to control the ventilation or HVAC systems in order to intelligently control the air flux while optimizing the energy consumption of the building.