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Editorial: Sensors for Air Quality Monitoring, Indoor and Outdoor

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Editorial on the Research Topic

Sensors for Air Quality Monitoring: Indoor and Outdoor

Sensors for air quality monitoring have quickly gained popularity due to increased concerns related to air pollution and spread of air contaminants both indoors and outdoors. The protracted experiences of lockdowns, self-quarantines, use of facemasks during the coronavirus pandemic (COVID-19) put the air quality issue in the spotlight worldwide, and have made people more environmentally and health aware.

The increasing availability and applicability of sensors for air quality monitoring offers the possibility to design and prototype customized low-cost sensor systems (LCSS) and multisensor platforms easier than ever before, not only for research or industrial purposes, but also for personal exposure assessment, complementary network measurements, educational training, and student projects (Lenartz et al.; Höfner et al.). Sensor-based intelligent systems have entered our daily life and found an increased use in health, environmental, and safety-related applications, thanks to the remarkable improvements on sensing materials and device performance. Significant efforts have been done to achieve increased sensitivity, selectivity, long-term stability, reproducibility, as well as decreased response time and operation temperature (Saruhan et al.; Domènch-Gil et al.). Moreover, proper calibration, rigorous data analysis, evaluation and validation methods are key factors of substantial improvement of sensor performance and enhanced reliability of concentration readings (Lenartz et al.).

Advances in materials research have played a crucial role for decades for the development of high-performance gas sensors. Metal oxide (MOx) semiconductor materials have been widely used since the 1950s to fabricate chemoresistive gas sensors due to their excellent sensing properties such as high sensitivity and long-term stability, possibility to control their properties by synthesis methods, ease of manufacture, cost effectiveness, and large-scale production potential compared to other types of gas sensors (Saruhan et al.; Domènch-Gil et al.). Among all, particular focus has been given to nanostructured SnO_2 and TiO_2 as outstanding MOx sensing materials. The review article by Saruhan et al. reports the most important achievements related to SnO_2 and TiO_2 over the past 2 decades. The effects of physical and chemical material characteristics, such as crystal structure, morphology, size, surface modification, bulk doping on the gas sensor properties are also described. It has been proven that MOx are suitable for detecting a large variety of gases and that the sensing properties can be tuned by, e.g., bulk-doping, heterojunctions or surface functionalization. However, MOx-based sensors usually suffer from poor selectivity due to their high sensitivity to several gas species, which is an issue that needs further research to be overcome.

An important factor to consider when fabricating micro or nanostructured MOx-based chemoresistive gas sensors is the amount and distribution of the structures that shape the sensing material, as they determine the gas sensing performance. The material characteristics can, therefore, enhance the sensitivity, selectivity, and working temperature for each relevant gas. In

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their work, the authors (Domènch-Gil et al.) propose a fast and cost effective fabrication method based on the synthesis and dielectrophoretic positioning of individual chains of monocrystalline indium oxide (In_2O_3) octahedral structures, which constitute the main sensing element. The sensors were exposed over 1 year to different concentrations of nitrogen dioxide (NO_2), carbon monoxide (CO), oxygen (O_2), ethanol (EtOH), methane (CH_4), and relative humidity (RH), diluted in synthetic air (SA) or nitrogen (N_2) atmospheres, showing high stability and no visible change in their behavior, drift, or deterioration of the surface structure. In the presence of RH above 30% and up to 80%, the sensors demostrated selectivity to NO_2, stability of response independent of the humidity level, and enhanced response time at higher RH. The authors envision future implementation of the demonstrated proof-of-concept fabrication methodology in CMOS-compatible microhotplate fabrication, thus expanding the possibilities to produce selective NO_2 sensors for air quality monitoring.

Quality of results depends, among other mentioned factors, on the sensor technology. For developing Antilope, a portable LCSS for assessment of air pollution exposure to nitric oxide (NO), NO_2, ozone (O_3), and PM, the authors (Lenartz et al.) choose electrochemical sensors due to their advantages compared to MOx-based sensors regarding lower power consumption, 2 mW against 500 mW, and higher selectivity to the target gases. On the other hand, they also report as drawbacks their lower lifetime expectancy, 18 months against 10+ years, and higher costs. The device was used in different settings including urban traffic station, cooking, indoor sport, and outdoor leisure activities. The authors demonstrate the potential for Antilope of working for complementary measurement and personal exposure assessment applications.

Breathing clean air is essential to prevent health problems related to the respiratory system, including viral infections. An easy way to assess indoor air quality (IAQ) and the effectiveness of proper ventilation, either natural or mechanical, is through the measurement of carbon dioxide (CO_2), particulate matter (PM), and total VOC (TVOC) levels, which are used as indicators of IAQ. Prolonged exposure to these common air pollutants may cause, e.g., fatigue, dizziness, lack of focus, and headache. In schools and classrooms, avoiding such symptoms by ensuring good IAQ means creating optimal conditions for learning (Höfner et al.). It is important to actively involve people in increased environmental awareness since early age, but merely providing facts or giving information about air pollution issues is not sufficient alone to achieve a sustainable change. Factual knowledge remains inert without application to complex or everyday situations. For this reason, the authors (Höfner et al.) propose active and problem-oriented approaches to situated learning in the form of experiments related to IAQ and sensor principles, interpretation of measurement results, and formulation of own research questions on air quality. Moreover, they highlight the importance to adapt the complexity of theoretical concepts, namely related to sensor principles and operation, to the students' level, not to overwhelm them. Enabling authentic learning scenarios by designing experiments related to everyday life allows students to directly transfer the findings from these measurements to their personal environment, with a direct impact on their environmental attitude and behavior.

AUTHOR CONTRIBUTIONS

DP has co-edited the Research Topic and wrote the Editorial article.

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