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Review

Solid-state gas sensors for breath analysis: A review

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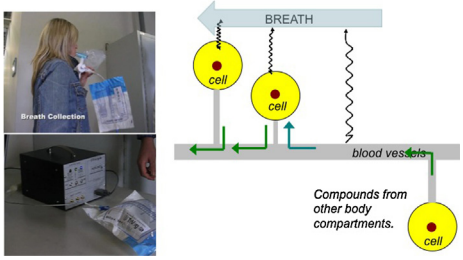
HIGHLIGHTS

- A review of the applications of the major sensor technologies in the field of breath analysis.
- A review of the diseases that could be diagnosed with solid-state sensors.
- A discussion about the sampling methods and the critical points in the analysis.

GRAPHICAL ABSTRACT



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ABSTRACT

The analysis of volatile compounds is an efficient method to appraise information about the chemical composition of liquids and solids. This principle is applied to several practical applications, such as food analysis where many important features (e.g. freshness) can be directly inferred from the analysis of volatile compounds.

The same approach can also be applied to a human body where the volatile compounds, collected from the skin, the breath or in the headspace of fluids, might contain information that could be used to diagnose several kinds of diseases. In particular, breath is widely studied and many diseases can be potentially detected from breath analysis.

The most fascinating property of breath analysis is the non-invasiveness of the sample collection. Solid-state sensors are considered the natural complement to breath analysis, matching the non-invasiveness with typical sensor features such as low-cost, easiness of use, portability, and the integration with the information networks. Sensors based breath analysis is then expected to dramatically extend the diagnostic capabilities enabling the screening of large populations for the early diagnosis of pathologies.

In the last years there has been an increased attention to the development of sensors specifically aimed to this purpose. These investigations involve both specific sensors designed to detect individual compounds and non-specific sensors, operated in array configurations, aimed at clustering subjects according to their health conditions. In this paper, the recent significant applications of these sensors to breath analysis are reviewed and discussed.

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1. Introduction

Analytical chemistry plays a conspicuous role in medical diagnostics. Advances in this discipline introduced a number of methodologies and instrumentations for the detection of target molecules in fluid, such as urine and blood, which can be sampled with a relatively minimum invasiveness for the subject.

Progresses in the analysis of gaseous samples stimulated the investigation of the volatile compounds that are found in the atmosphere surrounding the human body. The breath is surely the most rich and accessible body domain for the collection of endogenous volatile organic compounds (VOC). Therefore, breath analysis is rapidly emerging as a fascinating application field for the modern analytical chemistry. Furthermore, VOC analysis is attractive in medicine because of its absolutely non-invasive character, and it can be applied to any stage of the life.

The correlation between VOC and health was well known in the old clinical practices. Indeed, modern medicine takes advantage of the instruments offered by the technological progress, but in the past physicians interacted with the body of the patient using all the senses, olfaction included.

Nowadays, the introduction of diagnostics instruments makes less relevant sensorial inspection of the body, and this almost disappeared practice is rather confined to the realm of anecdotes [1].

Since the seventies, the improvement of instrumental analysis of VOC led to reconsider their role in medicine. The seminal paper of Linus Pauling [2] defined the frame for the definition of VOC profile out of a human body. This could be considered the basis for the finding of anomalies that can be connected to specific pathologies.

A number of studies appeared in the last decades correlates the presence of VOC in breath to some specific disease. The quest of biomarkers, univocally connected to pathologies, has been thwarted by the fact that many diseases are related to patterns of VOC instead than individual specific compounds. These researches are reassumed by a number of review papers and they will not be further reviewed here [3–5].

An additional burst to the interest in VOCs analysis for medical purposes has been provided by the development and the diffusion of solid-state chemical sensors. The impact of these devices and their possible applications is discussed in this review paper considering the case of breath analysis.

Breath is the natural interface for the extraction of VOC from the living bodies. Inhaled air, besides O_2 and N_2, contains a number of compounds present in the environment. On the contrary, as a result of the respiration, exhaled air is partially depleted of O_2, enriched of CO_2, and contains the VOC resulting from the interaction with the environment and the metabolic processes.

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