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Review Article

Cellulose-based micro/nanoparticles potentials for breath biomarker detection systems

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ABSTRACT

With the accelerating development of biomedical science, biomarker detection has emerged as a powerful tool for the diagnosis of several serious metabolic diseases, the breath-exhaled volatile compound detection represents one of the most quick, time-saving non-invasive, and cost-effecting approaches that deserve to be deeply investigated; the big challenge for this area is the developing of the most specific and selective sensing systems; the material science is considered one of the promising choices; and cellulose-based micro/nanoparticles are a valuable platform for sensor development.

Keywords: Breath bio-markers, Cellulose microspheres, Sensors, Volatile compounds

INTRODUCTION

The human-exhaled breath is generally composed of nitrogen, oxygen, carbon dioxide, and argon in addition to water vapor,[1] the major exhaled volatile organic compounds in the human breath are saturated hydrocarbones (ethane, pentan, and their fractions), unsaturated hydrocarbones (isoprene), oxygen-containing compounds (acetone), sulfur-containing compounds, nitrogen-containing compounds (ammonia), organic volatile compounds exhaled in breath have a strong connection with status of many of biochemical processes in the body as they are produced in different physiological (normal) and pathophysiological (abnormal) conditions,[2] and volatile organic compounds (VOG) in the exhaled breath are either endogenous (metabolic) or exogenous (previous environmental exposure).[3]

In spite of the fact that breath-based metabolomic detection systems have been implemented for the diagnosis of some metabolic diseases, but they still have many challenges to effectively integrate the traditional approaches.[4] Sensors equipped with nanomaterial-based detection systems may represent one of the most promising approaches in breath biomarker detection in comparison with other systems.[5] Nanomaterial-based breath sensing systems have many properties toward more sensitivity and fast response time.[6] For the breath biomarker sensors to be put in clinical use, there is a need for more efforts to overcome the challenges related to the precise analytical used techniques, sensitivity in addition to the matter of the limit of detection.[7]

Nanomaterials with its diverse composition and unique characteristics such as size and morphology bring an extra specification to the detection systems, such as increase sensitivity and selectivity in addition to response time.[8] The integration of nanocellulose with nanoparticles can increase the resultant system sensitivity.[9] The aim of this review is to address the issue of

constructing sensing platform for medical applications in exhaled breath biomarker detection integrated system based on simple, high sensitive, non-destructive, quick, eco-friendly cellulose-based nanomaterials.

METHODOLOGY

The most recent and relevant publications were collected and screened and the most relevant were focused on. The aim of this review is to shed the light on cellulose-based micro/nanoparticles for volatile biomarker detection in an attempt to direct future efforts toward more investigation to maximize the spectrum of this tool. The detection methodologies or techniques (chemical principles) are not discussed because it is out of the scope of this review.

DISCUSSION

In a study, cellulose nanofibers (CNFs) and 2,2,6,6-tetramethylpiperidine-1-oxyl-oxidized CNFs were prepared gas detection, the output indicates that nanocellulose-based sensors were successfully fabricated using a low-cost process and a bio-based platform. Has a good sensitivity for the detection of various water-soluble gases such as acetone, ammonia, methane, and at the ambient conditions with a detection limit range of 1–5 ppm within a detection time of <10 min.[10]

In another study to detect H_2S gas at room temperature, a detection system of cellulose acetate-based nanofibers was easy fabricated and it revealed a high performance with lower detection limits of 1 ppm in addition to a fast response of 22.8 s and a good reproducibility and a long-term stability.[11] In another study, a highly sensitive ammonia (NH_3) gas sensor with core-shell microspheres based on polystyrene was developed. The sensor response increased as the diameter of the microspheres increased, the high sensitivity of the resultant system was thought to be possibly attributed to micrometer-sized spherical particles.[12]

Moreover, another study revealed that zinc oxide (ZnO)/microcrystalline cellulose-based carbon sensor can detect ammonia that the previous pure ZnO ammonia sensor could not at room temperature which was attributed to the fact that the ZnO/microcrystalline cellulose-based systems provide more active sites for ammonia molecules. İt was found that this new system has a great gas-sensing response, stability, and selectivity to an ammonia concentration of 200 ppm.[13] and within the same context, a study for the colorimetric detection of H_2S with nanocrystalline cellulose (NCC)-based sensor depending on the reaction of H_2S with lead acetate, the experimental data revealed that the presence of NCC played a positive role in the mediation of the formation of NCC/ lead sulfide (PbS) complex in addition to its role as a stabilizer to prevent the precipitation of PbS. The thing highlights the positive impact of nanocellulose structure in improving the detection system performance for H_2S detection.[14]

Furthermore, in a study, a nanofiber/carbon nanotube hybrid foam sensor based on cellulose was designed to detect humidity, the results indicated that the porous structure of the obtained sensor showed a high humidity sensitivity by providing a more contact interface for water molecules adsorption in addition to the regulation of the sensor conductivity toward the more humidity sensitivity.[15]

Ksenofontov *et al.* designed an ethyl cellulose-based fluorescent sensor to detect the ethanol vapor, the system's optical signals is based on the rapid fluorescence quenching in the presence of ethanol vapor with an instant response at detection limits of 0.56 ppt, and the results indicated that this system was very sensitive and selective to ethanol vapor so it can be used to detect ethanol in the exhaled breath;[16] furthermore, Qi *et al.* reported that the cellulose-based nanotube aerogels were able to detect several volatile organic compounds such as methanol, ethanol, and toluene, in addition to other volatile compounds with a high sensitivity and reproducibility and this could be attributed to the highly porous networks of these systems.[17]

CONCLUSION

It is clear that there are many positive indicators that can be extracted that support the introduction of the cellulose-based nano/microsphere systems as a potential tool for the breath volatile biomarker detection systems and that there is always an added value when combined or integrated with the traditional in place systems.

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