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Abstract

Development of NOx Gas Sensor Based on Electrospun ZnO Nanofibers for Diagnosing Asthma Disease †

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Abstract: Volatile organic compounds (VOCs) have the potential to serve as biomarkers for respiratory diseases such as asthma. Non-invasive respiratory analysis can be used for early detection and disease monitoring. This paper presents the development of a ZnO metal oxide nanofibers sensor as a cost-effective method for detecting NO, which is an asthma biomarker, and NO_2, that can cause asthma. Electrospun metal oxide nanofibers are considered for gas sensor applications due to their unique structural and electrical properties. The results indicate that the amount of zinc acetate and the morphology of the ZnO nanofibers as a sensing medium can affect the sensitivity of the gas sensor. The preparation of electrospinning solutions containing varying amounts of zinc acetate must be carefully considered due to its impact on morphology and thus sensitivity.

Keywords: asthma biomarker; ZnO metal oxide nanofibers; gas sensor; electrospinning; NO detection

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1. Introduction

Early detection and disease monitoring can help control the severity of the disease and improve treatment, which can reduce cost. Among the materials used for producing sensors, metal oxides (MOs) are one of the most promising sensing materials in chemoresistor gas sensors [1,2]. The aim of this study was to investigate the influence of different percentages of zinc acetate in the precursor solution for electrospinning on the sensitivity of electrospun ZnO for NO_x gas sensing. NO gas in concentrations of 1, 2.5, 5, and 10 ppm and NO_2 gas in concentrations of 500 ppb, 1, and 2.5 ppm were investigated at 275 and 300 °C.

2. Materials and Methods

Poly (vinyl alcohol) (PVA) (MW = 89,000–98,000 and 99+% hydrolyzed) and zinc acetate dihydrate ((CH3CO2)2Zn) (ZnAc) obtained from Sigma Aldrich Corp (Chesnes, France) were utilized without any further processing or refining. The samples were produced and characterized using an electrospinning cabin (Fluidnatek/LE 50, Bioinicia, Spain), a calcination system (Nabertherm Co., 30–3000 °C, Lilienthal, Germany), and a Scanning Electron Microscope (SEM) (Phenom ProX, Thermo Fisher Scientific, Waltham, MA, USA). Half (PVA:ZnAc (1:0.5)) and equal (PVA:ZnAc (1:1)) ZnAc concentrations were used regarding PVA in order to analyze the influence of the ZnAc concentration on sensitivity.

3. Results and Discussion

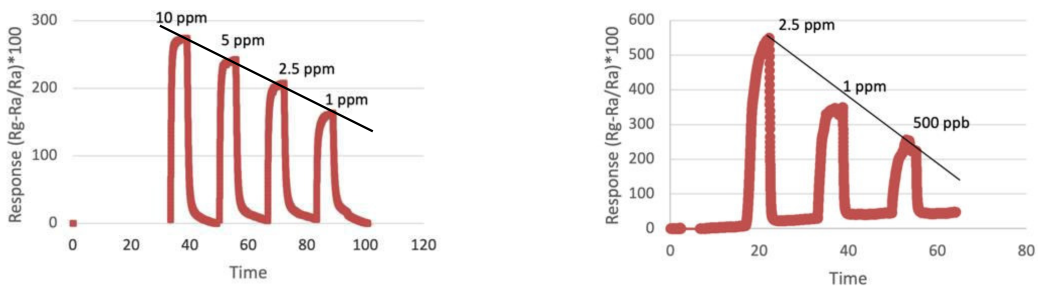
3.1. Samples Fabrication and Morphology

An aqueous solution of PVA (15 wt%) and ZnAc in two different concentrations was dissolved in distilled water. In the electrospinning process, the spinnability of the solutions with half zinc acetate ($S_{0.5\ Zac\text{-}PVA}$) and equal zinc acetate ($S_{1Zac\text{-}PVA}$) was influenced by their viscosity, conductivity, and surface tension. Our results show that higher concentrations of zinc acetate result in increased viscosity. To achieve optimal electrospinning conditions, we employed Design of Experiments (DOEs) software to obtain homogenous nanofibers without beads or solvent residue. To obtain ZnO nanofibers, the composite nanofibers were subjected to calcination at a rate of 0.5 degree/hour in air at 600 °C for a duration of 2 h.

3.2. Measurement of Gas Sensors

To determine sensitivity, the nanofibers were directly collected on the interdigitated electrode, placed in a chamber, and connected to a homemade device designed to acquire data. The two sensors of $S_{0.5\ Zac\text{-}PVA}$ and $S_{1Zac\text{-}PVA}$ were characterized for NO and NO_2 gases, and the results were compared regarding the amount of zinc acetate. $S_{0.5\ Zac\text{-}PVA}$ showed a lower response towards both gases in comparison to $S_{1Zac\text{-}PVA}$, attributing it to a lower amount of ZnO in the sensor. Sensor $S_{1Zac\text{-}PVA}$ demonstrates a greater response to 10 ppm NO and 2.5 ppm NO_2 at temperatures of 300 °C and 275 °C, respectively.

The response of sensor $S_{1Zac\text{-}PVA}$ towards the gases at 300 °C is demonstrated in Figure 1. As shown, the sensor at 2.5 ppm is more sensitive to NO_2 compared to NO. The lower sensitivity of the sensor in detecting NO gas may be attributed to NO conversion into NO_2.



(**a**) (**b**)

Figure 1. Dynamic response curves of sensors $S_{1Zac\text{-}PVA}$. (**a**) Response to NO gas in 1, 2.5, 5, and 10 ppm at 300 °C. (**b**) Response to NO_2 gas 0.5, 1, and 2.5 ppm at 300 °C.

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