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Abstract

Low-Cost Sensors Based on Nanoparticles of Tin Dioxide Decorated with Graphene Used to Detect Ultra-Low NO_2 Concentrations at Room Temperature †

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Abstract: Chemical nanosensors based on nanoparticles (NPs) of pure tin dioxide (SnO_2) and graphene-decorated tin dioxide were developed and characterized for the detection of pollutant gases. Sensitive layers were prepared by a drop casting method. The photoactivation of the sensors allows for the detection of ultra-low NO_2 concentrations (50 ppb) at room temperature. The sensors show strong responses to NO_2 and weak ones to the other tested polluting gases (CO, CH_4 and CO_2). The effect of humidity and the presence of graphene on the sensors' response were studied.

Keywords: gas sensor; semiconductor oxide; nanoparticles; pollutant gases; NO_2; graphene; photoactivation

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1. Introduction

One of the pollutants of greatest concern is NO_2 due to the unprecedented increase in quantity that has been experienced in recent decades. NO_2 causes a variety of adverse effects (health and environment). In recent years, with the development of the Internet-of-Things (IoT) technology, there has been an emerging market demand for low-cost and miniaturized gas sensors to be incorporated into portable devices.

In this paper, a simple, economical, versatile and potentially scalable method is proposed to prepare low-cost sensors by a drop-casting technique using automated equipment. In addition, the substrates employed, low-cost substrates (FR-4) suitable for use in the field of gas sensors, will also contribute to the development of more economical and versatile sensors. We present two low-cost resistive sensors based on SnO_2-NPs (pure and decorated with graphene) to detect pollutant gases at room temperature.

2. Materials and Methods

SnO_2-NPs (<100 nm particle size) and graphene dispersion (1 mg/mL in DMF) were purchased from Sigma Aldrich. The sensitive layers were obtained by drop-casting SnO_2-NPs dispersions (2.5 mg/mL in water) on FR-4 substrates with interdigitated electrodes. The graphene-decorated samples were obtained by incorporating a certain amount of graphene dispersion (200 ppm %wt) into the SnO_2 dispersions.

SEM/EDX analysis was used to investigate the surface morphology and the elemental composition of the sensors. The sensors were characterized using an automated gas line.

3. Discussion

The photoactivation with UV-LED of the sensitive films allows for the sensors to operate at room temperature. A comparative study of detection performance between the SnO_2–NPs sensors and graphene-decorated SnO_2-NPs sensors was carried out considering different concentrations of pollutant gases at room temperature. The influence of humidity on the response of the sensors was also studied. The detection mechanisms in both atmospheres are discussed.

Figure 1 illustrates the dynamic response at room temperature of the sensors tested under UV illumination. In general, all the sensors exhibited a high sensitivity and selectivity to NO_2, detecting concentrations as low as 50 ppb. The responses of the sensors in humid air (Figure 2) were, in all the cases, better than those obtained in dry air. The graphene-decorated SnO_2 sensors present an improvement in the NO_2 response.

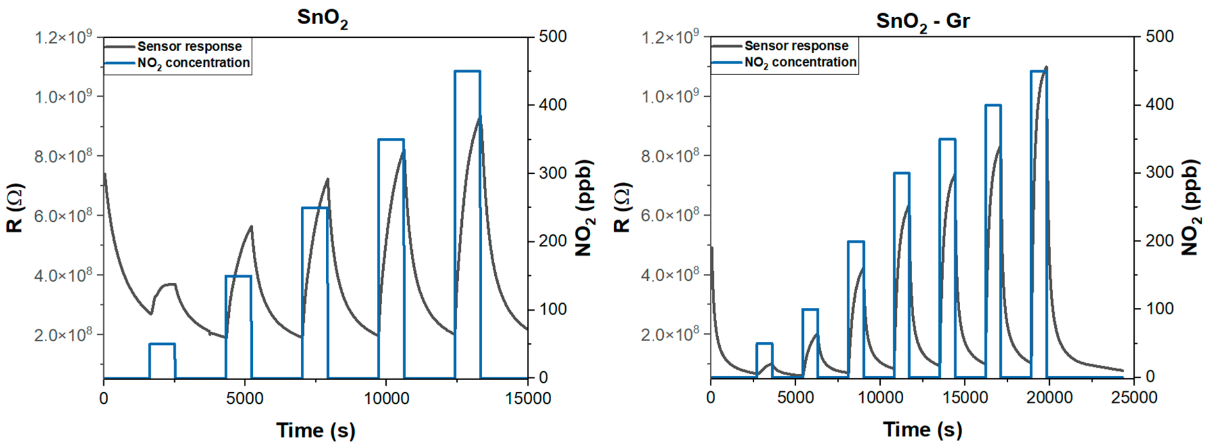

Figure 1. Dynamic response curves (black curve) of the sensors' sensitivity to different NO_2 concentrations (blue curve) at room temperature in humid air (50% RH) and under UV-LED lighting conditions.

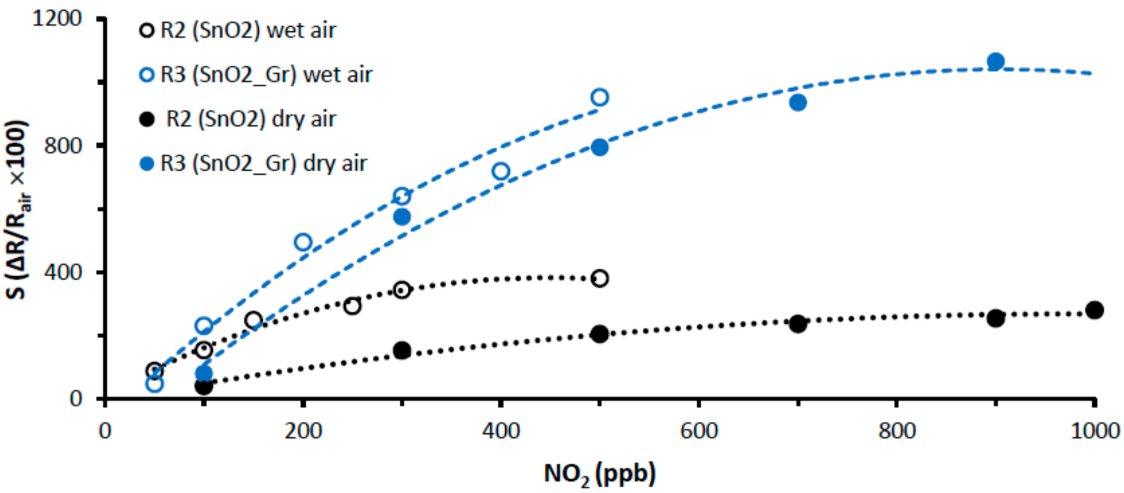

Figure 2. Calibration curves of sensors' sensitivity in dry and humid air (50% RH) to NO_2, at room temperature in humid air (50% RH), and under UV-LED lighting conditions.

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