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(Research Article)

Temperature-dependent variation in ammonia sensing properties of ZnO-GO nanocomposites

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Abstract

Industrialization has caused significant environmental and health risks due to the emission of hazardous gases like ammonia. This study investigates the temperature-dependent gas sensing properties of a ZnO-GO nanocomposite synthesized via microwave-assisted combustion. The ammonia sensor, tested from 25 °C (room temperature) to 200 °C, showed its highest sensitivity (72 %) at 100°C for 100 ppm ammonia. It achieved a response time of 94 seconds and a recovery time of 58 seconds. These results demonstrate the potential of ZnO-GO nanocomposite sensors in reducing ammonia-related risks in industrial environments.

Keywords: Nanocomposite; Ammonia sensor; Zinc oxide-graphene oxide (ZnO-GO); Hazardous gases

1. Introduction

The rapid industrial evolution in recent decades has introduced many environmental and human health dispute, primarily due to the emission and leakage of hazardous gases such as NH_3, C_2H_6O, CH_3OH, and C_3H_6O, *etc* [1-3]. Particularly Ammonia is widely used in industries like agriculture, refrigeration systems, and chemical manufacturing, etc. where its accidental emission poses considerable risks to human health and the environment [4, 5]. Exposure to ammonia can cause respiratory issues, skin related issues, and in intense cases, life-threatening conditions [6, 7]. Accordingly, the need for efficient and reliable gas sensors has become more imperative to assure continuous monitoring and sensing of such noxious gases in industrial sector.

Gas sensors, particularly those based on metal oxide nanocomposites, are attracting attention owing to their high sensitivity, accelerated response, and capability to work under changing environmental conditions [8-10]. Zinc oxide (ZnO) nanostructure, in particular, have been extensively studied for gas sensing applications attributed to its firmness and excellent semiconducting properties [11, 12]. However, the performance of ZnO sensors can be further increased through the incorporation of graphene oxide (GO), which improves electrical conductivity, surface interactions, and allows for better gas adsorption as well as desorption [13, 14].

The present study focuses on synthesizing a ZnO-GO nanocomposite using a microwave-assisted combustion method and investigating its temperature-dependent ammonia sensing properties. The ZnO-GO nanocomposite sensor was tested across a temperature range from 25 °C to 200 °C. The ZnO-GO nanocomposite ammonia sensor shows highest response of 72 % at 100 °C with admirable response and recovery time of 94 and 58 sec respectively. The findings of this study suggest that ZnO-GO nanocomposites could play a critical role in decrease the risks associated with ammonia emissions, making them a highly promising material for gas sensor development.

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2. Experimental details

The ZnO-GO nanocomposite was synthesized using a cost-effective microwave-assisted combustion method. Zinc nitrate hexahydrate [$Zn(NO_3)_2 \cdot 6H_2O$] was mixed with powdered table sugar. The mixture was heated in a microwave oven at 350 W for 20 minutes, during which the sugar underwent rapid combustion. The resulting product was then annealed at 450 °C for 2 hrs to improve crystallinity and ensure proper interaction with graphene oxide (GO). The final black powder, the ZnO-GO nanocomposite, was subsequently used for further measurements, along with structural and morphological characterization using techniques like X-ray diffraction (XRD) and scanning electron microscopy (SEM) to confirm successful synthesis and evaluate its properties.

3. Results and discussion

The successful formation of the ZnO-GO nanocomposite was confirmed using XRD and SEM measurements. The XRD pattern of ZnO-GO, shown in Fig. 1a, demonstrates diffraction peaks at (100), (002), (101), and (102), (110), (103), and (112) corresponding to the JCPDS card 36-1451. In Fig. 1b, the SEM image reveals a uniformly distributed of ZnO nanoparticles embedded within the GO matrix indicating strong interactions between ZnO and GO.

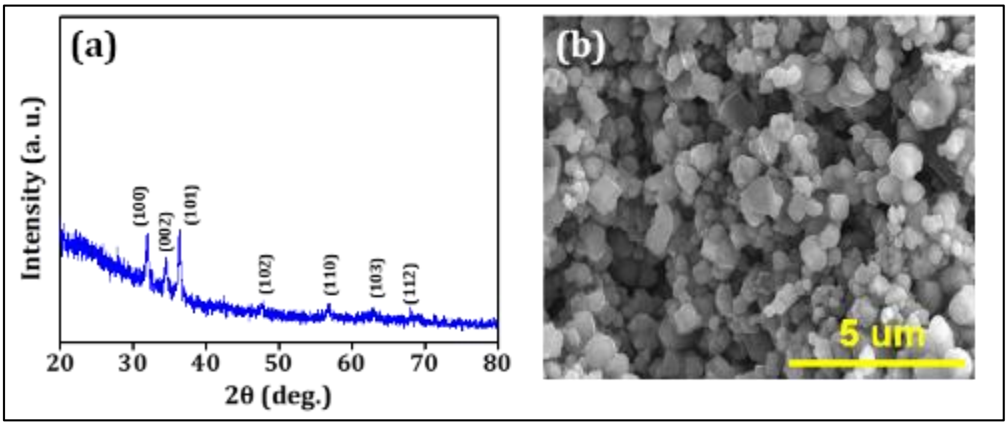

Figure 1 a) The XRD pattern, and b) SEM image of ZnO-GO nanocomposite

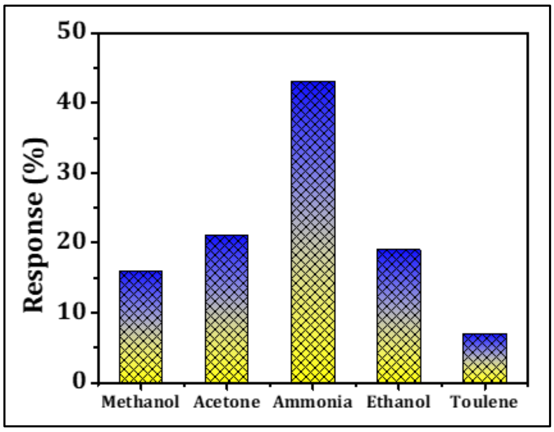

Figure 2 The selectivity of the ZnO-GO nanocomposite against various VCs

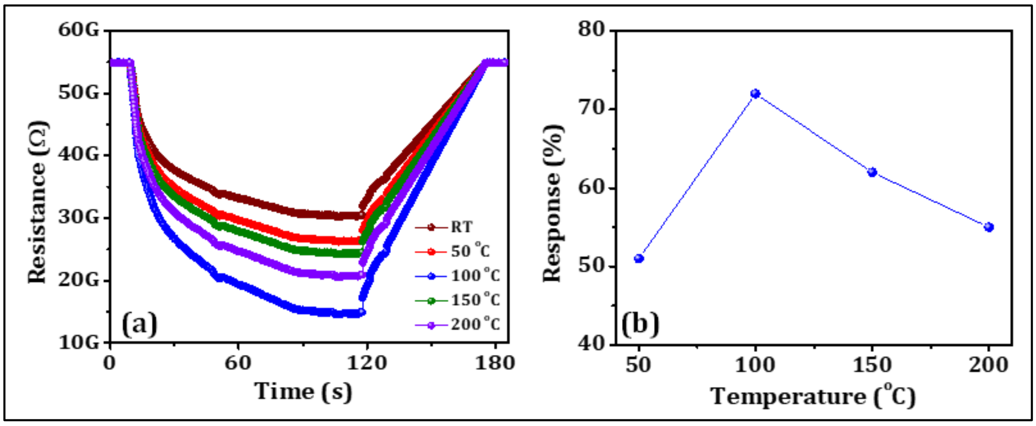

Figure 3 The effect of temperature on the gas sensing performance of the ZnO-GO nanocomposite

The selectivity of the ZnO-GO nanocomposite was measured for various volatile compounds like Methanol, Acetone, Ammonia, Ethanol, and Toulene @ room temperature at 100 ppm and shown in Fig. 2. It was observed that, the ZnO-GO nanocomposite shows highest response for ammonia. The further measurements were carried out for ammonia only at higher temperatures *i. e.* RT (25 °C), 50, 100, 150, and 200 °C which is shown in Fig. 3a. The highest response for ammonia was observed at 100 °C attributed to the availability of active sites of the ZnO-GO nanocomposite surface. The response towards ammonia sensor as a function of temperature is revealed in Fig. 3b which indicates the highest response at 150 °C.

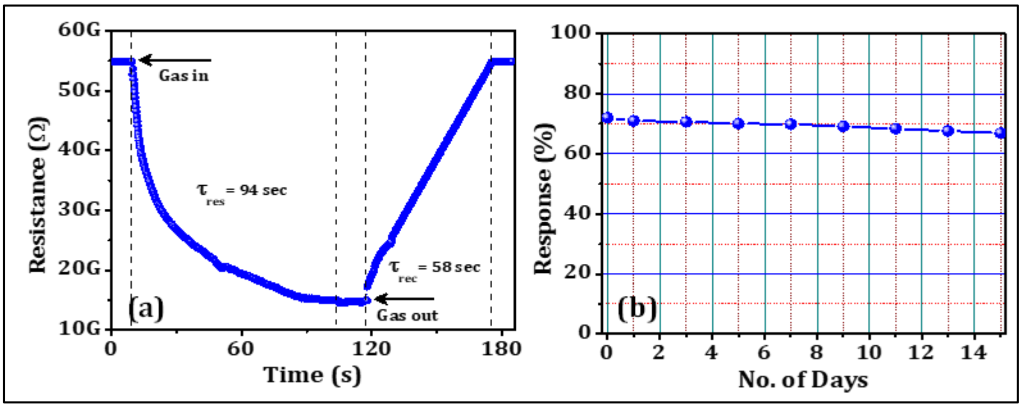

Figure 4 a) The response and recovery curve, and b) Durability test of the ZnO-GO nanocomposite against ammonia

The response/recovery cure of the ZnO-GO nanocomposite against ammonia is shown in Fig. 4a. The ZnO-GO nanocomposite shows the highest response of 72 % with the considerable response and recovery time of 94 and 58 seconds respectively indicating the worth of the ZnO-GO nanocomposite as an ammonia sensor. The durability test of the ZnO-GO nanocomposite as an ammonia sensor was carried out up to 15 days and shown in Fig. 4b. The ZnO-GO nanocomposite shows stable response of 92.82% even after 15 days.

4. Conclusions

The ZnO-GO nanocomposite was successfully synthesized using cost-effective and user-friendly microwave assisted combustion technique and confirmed by XRD and SEM analyses. The ZnO-GO nanocomposite demonstrated excellent gas sensing performance, with a 72% maximum response to ammonia and fast response and recovery times of 94 and 58 seconds respectively at 150 °C at 100 ppm concentration. The performance was temperature-dependent, enhancing its suitability for ammonia detection. Durability tests showed stable response (92.82%) even after 15 days, highlighting its robustness and long-term reliability. These results make the ZnO-GO nanocomposite a promising material for efficient, real-time ammonia sensing in industrial and environmental applications.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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