

Rapid and Selective Sub-ppm Hydrogen Sulfide Detection using rGO/ In₂O₃ Heterojunction Sensor

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Summary:

Trace level detection of toxic gases using chemiresistive sensors remain a significant challenge. In this work, spin coated reduced graphene oxide/ Indium oxide nanocomposite sensor was developed for hydrogen sulfide sensing. The sensor showed rapid response and concentration dependent sensing behavior at the optimized operating temperature. The improved sensing performance is attributed to structural defects, porous morphology, and heterojunction assisted interfacial effects in the nanocomposite. These results highlight the potential of the nanocomposite for trace level hydrogen sulfide detection.

Keywords: rGO/ In₂O₃ heterojunction, hydrogen sulfide sensing, sub-ppm detection, porous morphology, chemiresistive sensor

Title

Rapid and Selective Sub-ppm Hydrogen Sulfide Detection using rGO/ In₂O₃ Heterojunction Sensor.

Background, Motivation and Objective

H₂S is a highly toxic and corrosive gas, and its reliable detection at low concentrations is essential for environmental monitoring and health protection. Although metal oxide semiconductor sensors have been widely studied for H₂S sensing, their practical use is often limited by poor selectivity. In this context, rGO-based heterostructures have attracted considerable attention because of their large surface area, porous morphology, and ability to promote rapid charge transport [1]. In₂O₃ is also a promising sensing material due to its good electrical conductivity, chemical stability, and defect-assisted surface activity [2]. In this work, a sol gel assisted spin coated rGO/ In₂O₃ nanocomposite sensor is developed for enhanced H₂S detection, with emphasis on the role of heterojunction assisted interfacial effects in the sensing mechanism.

Description of the New Method or System

This work presents a sol gel assisted spin coated rGO/ In₂O₃ nanocomposite sensor for selective trace level H₂S detection. The novelty lies in integrating rGO with In₂O₃ to create a heterojunction-based sensing platform that combines enhanced charge transport with defect rich surface reactivity. The sensor achieved sub-ppm detection down to 0.5 ppm and showed a response of

$66 \pm 2 \%$ at 4 ppm H₂S at an operating temperature of 250 °C. The observed performance is attributed to structural defects, porous morphology, which assists adsorption, and interfacial resistance modulation within the nanocomposite. Graphene oxide was synthesized by a modified Hummers' method and mixed with In₂O₃ precursor to form a homogeneous coating solution. The sensing film was deposited by spin coating, followed by preheating and annealing to obtain the active layer as shown in Fig. 1. These results demonstrate a simple and scalable approach for improved H₂S sensing.

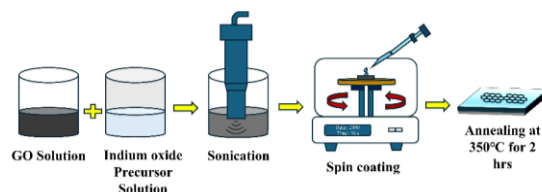


Fig. 1. Schematic diagram of spin coated rGO/ In₂O₃ thin film.

Results

Structural and Morphological Investigations

Fig. 2 (a) shows the XRD patterns of the rGO/ In₂O₃ composite films, confirming the polycrystalline cubic bixbyite structure of In₂O₃. The characteristic rGO peak was not distinctly visible, likely due to its low concentration and weak diffraction intensity. Fig. 2 (b) shows the Raman spectra with the characteristic D and G bands,

further confirming the successful formation of the rGO/ In₂O₃ composite sensing layer.

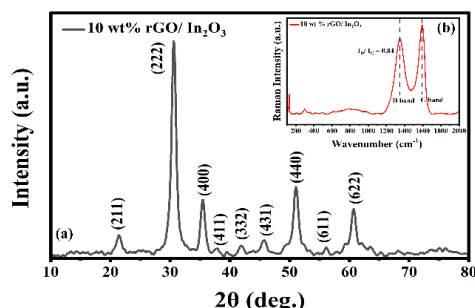


Fig. 2. (a) XRD pattern (b) Raman spectra of rGO/ In₂O₃ nanocomposites.

Fig. 3 (a) shows the surface morphology of the rGO/ In₂O₃ film, indicating a porous nanostructured surface. Fig. 3 (b) shows the EDX spectrum, confirming the elemental composition of the nanocomposite sensing layer.

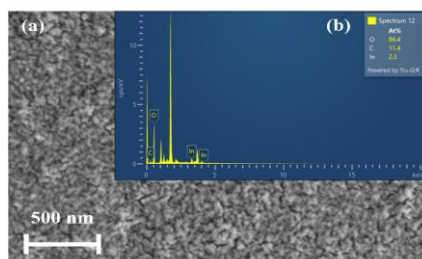


Fig. 3. (a) FESEM and (b) EDS spectra of rGO/ In₂O₃ nanocomposites.

Gas Sensing Measurements

Fig. 4 illustrates the gas sensing mechanism of the rGO/ In₂O₃ nanocomposite, governed by oxygen adsorption and heterojunction assisted charge modulation at the interface. In air, adsorbed oxygen species induce electron depletion, while exposure to H₂S releases electrons back to the sensing layer and decreases the resistance. The enhanced response is attributed to interfacial charge transfer and surface reactions within the nanocomposite.

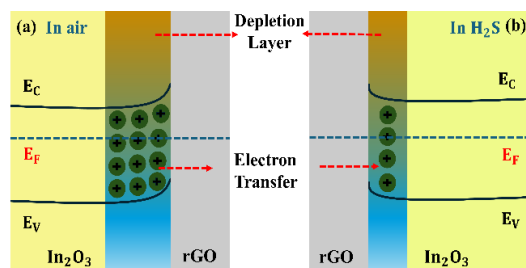


Fig. 4. Schematic representation of rGO/ In₂O₃ gas sensing mechanism (a) in air (b) in H₂S.

Fig. 5 shows the dynamic response curves of the sensor, revealing a progressive increase in

response with increasing H₂S concentration and confirming effective concentration dependent sensing. The response and recovery times, along with the sensor response values, are summarized in Tab.1. The sensor response was calculated using Eq.(1).

$$\text{Sensor Response (\%)} = \frac{R_a - R_g}{R_a} \times 100 \quad (1)$$

The response process was consistently faster than recovery, suggesting rapid surface adsorption followed by slower desorption. The sensor achieved a maximum response of $66 \pm 2\%$ at 4 ppm H₂S and detected concentrations as low as 0.5 ppm, demonstrating its potential for trace level gas monitoring.

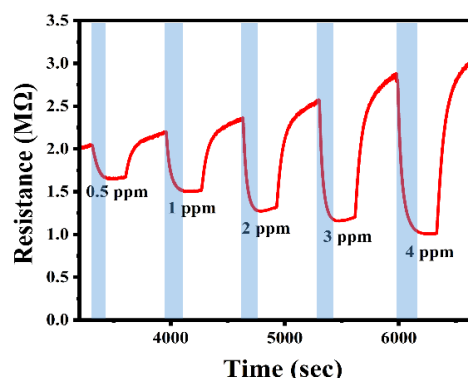


Fig. 5. Dynamic response curves of rGO/ In₂O₃ gas sensor for varying H₂S gas concentration.

Tab. 1: Response Time, recovery time and sensor response of rGO/ In₂O₃ sensor.

Concentration (ppm)	Response Time (s)	Recovery Time (s)	Sensor Response (%)
0.5	69 ± 6	141 ± 26	18 ± 6
1	76 ± 7	153 ± 18	30 ± 5
2	80 ± 7	174 ± 12	39 ± 10
3	73 ± 7	167 ± 15	57 ± 1
4	119 ± 12	168 ± 7	66 ± 2

References

- [1] P. Leangtanom, A. Wisitsoraat, A. Tuantranont, N. Chanlek, P. Pookmanee, S. Satienperakul, S. Phanichphant, V. Kruefu, Microwave-assisted hydrothermal/ impregnation synthesis of Cu₂O-decorated rGO/ In₂O₃ nanorices for sensitive SO₂ gas sensors, ACS Applied Nano Materials 6, 12980-12990 (2023); doi: 10.1021/acsanm.3c01712.
- [2] Tanya Sood, Saikat Chattopadhyay, P. Poornesh, Predictive mixed-gas detection using rGO/ In₂O₃ nanocomposite sensors assisted by machine learning, Nanoscale Advances 8, 1958-1974 (2026); doi: 10.1039/D5NA01092F.