

Highly Selective Ethanol Sensor Based on SnO₂/MWCNTs Nanocomposite

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Summary:

SnO₂/MWCNTs-based ethanol sensor was fabricated using RF magnetron sputtering and e-beam deposition techniques. The linear dependence of the sensor response on ethanol concentration enabled the determination of its concentration in the range of 1-100 ppm, with response and recovery times of 17 and 26 s, respectively. The sensor demonstrated ultra-high selectivity for ethanol vapor relative to acetone, propylene glycol, water, ammonia vapor, methane, and carbon dioxide.

Keywords: gas sensor, ethanol vapors, tin oxide, CNTs, magnetron sputtering

Introduction

Nowadays, the detection of ethanol (ethyl alcohol) is critical for ensuring public safety, verifying regulatory compliance in industries, and health monitoring. It is crucial for detecting environmental leaks, controlling fuel quality in biofuel blending, and analyzing post-mortem samples in forensics. Ethanol detection using metal oxide semiconductor sensors is valued for their low cost, portability, high sensitivity, and real-time monitoring capabilities, which are essential for identifying gas concentrations [1].

Metal oxide (MOX) nanomaterials (e.g., SnO₂, ZnO, TiO₂, Fe₂O₃) are widely used as gas sensing materials, often doped with transition or noble metals (such as Ni, Cu, Os, Pd, and Pt) to enhance their sensing characteristics [2]. Moreover, a combination of MOX with single- or multi-walled carbon nanotubes (SWCNTs or MWCNTs) improves sensitive parameters such as gas response, response and recovery times, and operating temperature. Besides, they increase the effective surface area by creating additional adsorption sites, and at the same time, endow the sensors with flexibility, enhance conductivity, and stability [3].

Motivation and Novelty

Thus, conventional SnO₂-based gas sensors often suffer from limited sensitivity and selectivity to interfering gases. The integration of MWCNTs with SnO₂ offers a promising strategy to overcome these limitations by enhancing charge transport, increasing active surface area, and enabling synergistic interactions at the

nanocomposite interface. The fabricated SnO₂/MWCNTs nanocomposite is therefore expected to provide improved selectivity toward ethanol along with enhanced sensitivity, faster response, and better stability compared to conventional materials.

Experimental

The ethanol sensor was fabricated using RF magnetron sputtering from the Cu-doped SnO₂ target prepared earlier by the solid-state reaction method. The SEM image of the SnO₂ powder demonstrated that the grain sizes ranged over a fairly wide range, reaching up to several hundred nanometers. (Fig.1). The sensing film was deposited on the sensor substrate for 25 min using high-purity argon as a working gas, with a generator power of 70 W.

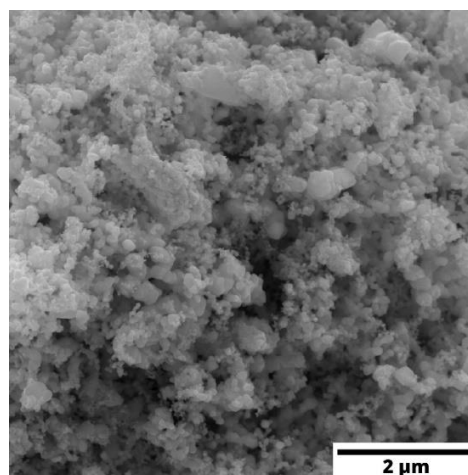


Fig. 1. The SEM image of the SnO₂ powder.

Subsequently, the MWCNTs were deposited onto the film surface by e-beam evaporation for 4 s, which caused the generation of the MWCNT islands on the surface of Cu-doped SnO₂ thin film. SEM image of MWCNTs revealed an intertwined network with diameters of approximately 30–150 nm and lengths of several micrometers, forming a porous architecture that promotes gas adsorption and diffusion (Fig. 2).

A schematic illustration of the fabricated sensing system is presented in Fig. 3.

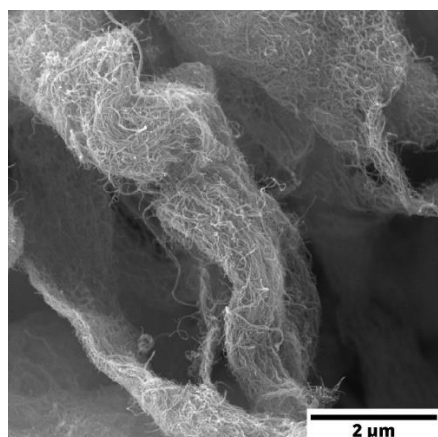


Fig. 2. The SEM image of MWCNTs.



Fig. 3. Schematic illustration of the ethanol sensor.

Results

The response of the sensor was defined as the ratio of its resistance in air and under ethanol exposure, respectively. The ethanol sensor demonstrated its best sensitivity at 150 °C operating temperature under 395 nm UV irradiation. Under those conditions, the sensor showed linear dependence of the response on ethanol concentrations in the range of 1–100 ppm (Fig. 4). The response of the sensor to 1 ppm of ethanol vapor was 1.4, while under exposure to 100 ppm of ethanol vapor, the resistance of the sensor was decreased 7 times.

The inset image of Fig. 4 demonstrated the dynamic resistance curve of the sensor with the injection of 10 ppm ethanol vapor into the chamber, representing a resistance change of 2.4 times. Besides, the response and recovery times of the sensor were 17 and 26 s, respectively.

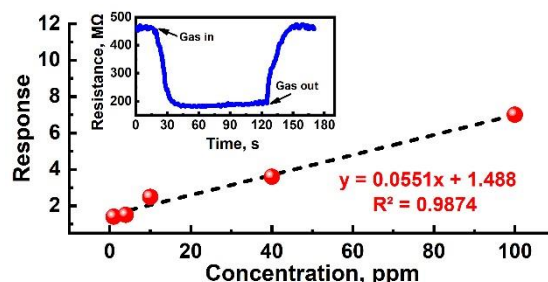


Fig. 4. Linear dependence of the sensor response on ethanol concentration (Inset image: dynamic resistance change of the sensor under 10 ppm ethanol exposure).

The SnO₂/MWCNTs sensor demonstrated ultra-high selectivity towards ethanol compared to the other interfering gases shown in Fig. 5. The sensor demonstrated no response to 400 ppm of acetone, 3000 ppm of water, 300 ppm of ammonia, and 600 ppm of propylene glycol vapors, and 5000 ppm of methane and carbon dioxide.

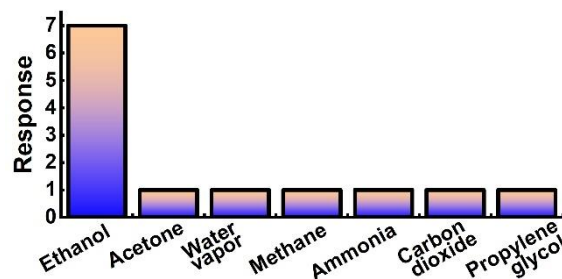


Fig. 5. Selectivity of the SnO₂/MWCNTs sensor.

Thus, the SnO₂/MWCNTs sensor demonstrated a fairly low detection limit for ethanol, high sensitivity, rapidity, and ultrahigh selectivity, making it a potentially applicable system.

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References

- [1] A. M. Laera, M. Penza, Chemiresistive materials for alcohol vapor sensing at room temperature, *Chemosensors* 12(5), 78 (2024); doi: 10.3390/chemosensors12050078
- [2] P. Siciliano, Preparation, characterisation and applications of thin films for gas sensors prepared by cheap chemical method, *Sensors and Actuators B: Chemical* 70, 153–164 (2000); doi: 10.1016/S0925-4005(00)00585-2
- [3] Y. Kong, Y. Li, X. Cui, L. Su, D. Ma, T. Lai, L. Yao, X. Xiao, Y. Wang, SnO₂ nanostructured materials used as gas sensors for the detection of hazardous and flammable gases: A review, *Nano Materials Science* (2021); doi: 10.1016/j.nanomns.2021.05.006