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CuO-loaded NiO based gas sensor with dual selectivity to NO_2 and H_2.

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Summary:

Heterostructures of copper oxide nanoparticles with different NiO loading, were synthesized by sol gel method and their detailed morphological and structural properties have been investigated by XRD, FESEM and EDS, FT-IR studies. Gas sensing devices were fabricated by printing thick film of the CuONiO nanopowders on conductometric ceramic platform. It has been successfully demonstrated that the CuO-NiO sensor has dual sensing capability, able to detect selectively hydrogen at the operating temperature of 80 ◦C, and NO_2 at the temperature of 220 ◦C.

Keywords: Hydrogen, Nitrogen Dioxide, Gas Sensor, Dual Sensor, Hybrid Nanostructure.

Introduction

Metal oxide-based semiconductors are low-cost materials that exhibit promising characteristics including high reactivity and surface area, designable structures, and tunable bandgap. Owing such properties, they are an optimal choice for gas sensors [1]. On other hand, there has been consistent effort to fabricate highly sensitive and selective sensors for monitoring and detection of gases for the biomedical and environmental sectors, such as hydrogen (H_2) and nitrogen dioxide (NO_2). These gaseous species are potentially harmful and even at very low concentration of these gases can cause adverse effects on human health. Therefore, there is a great demand to fabricate highly sensitive, selective, cost effective, rapid, and reliable noninvasive techniques for monitoring these pollutant gases.

As is well known, the response of gas sensors is related to the interaction of the target gas with the surface of the sensing layer. So, the sensor response can be modulated changing the sensing film and the operating temperature of the sensor. Herein, we investigated the selective detection of H_2 and NO_2 varying the operating temperature of the sensor developed based on thick film of CuO-NiO powders printed on a conductometric ceramic platform provided with a pair of interdigitated platinum electrodes.

2.Experimental details:

a. Synthesis of CuO-NiO Hybrids NCs

Hybrid nanocomposites were synthesized by a Sol-gel method [5]. First, CuO and NiO nanopowders were dissolved in 50 mL of HCl and citric acid, respectively. The mixture was sonicated for 30 min and then stirred vigorously at increasing temperature from 60 °C to 90 °C for 2-5 hours until the solution was converted into gel. Thereafter, the formed gel was dried at 90 °C for further 4 hours. Lastly, the dried sample was ground down into fine powder and stored for the further uses.

b. Gas Sensing Device Fabrication

Electrodes for gas sensing studies were prepared by printing thick films (~20 μm) of the composite powder on alumina substrates (6 × 3 mm2) provided with Pt interdigitated electrodes and a Pt heater placed on the backside. Before applying to the gas sensing tests, the prepared electrodes have been subjected to a low (80 ◦C) and high (250 ◦C) temperature thermal treatment.

Results and Discussion

a. Structural studies The XRD patterns of pure CuO, NiO and CuO/NiO nanocomposite are shown in Fig. 1. New reflection peaks, compared to ones observed on pure CuO and NiO, were noted, suggesting the presence of new phases likely linked to the CuO/NiO composites formed.

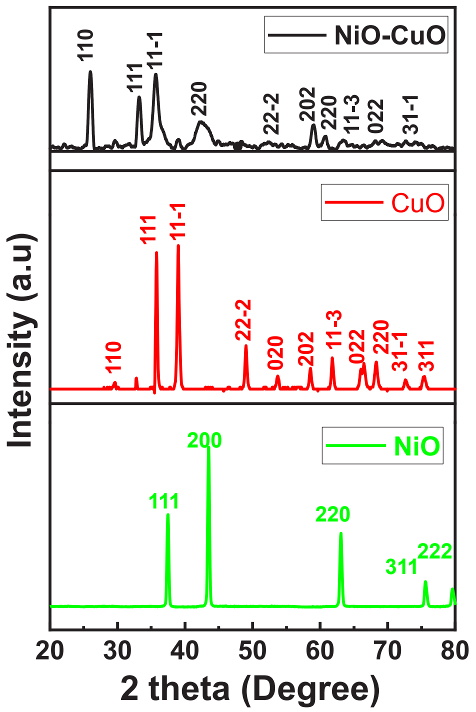

Fig.1. XRD graph of synthesized: CuO, NiO and CuO/NiO hybrids.

b. Gas Sensing tests.

The sensing properties of CuO/NiO hybrid sensors towards hydrogen were first investigated. To find the best operating conditions, the sensors were preliminarily exposed to 40000 ppm of hydrogen at different temperatures. As an example, in Fig. 2 is reported the variation of resistance at the introduction of hydrogen for the CuO/NiO hybrid sensor at the working temperature of 80 ◦C.

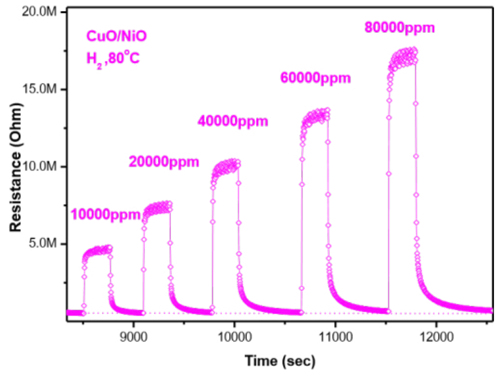

Fig. 7 (a). Transient response of CuO/NiO hybrid sensors to different concentrations of H2 at the optimal temperature of 80 ◦C.

(ii). NO_2 sensing tests.

Operating the sensor at the temperature of 220°C, we noted that the device shows very good performances for NO_2 sensing. The variation of resistance at the introduction of NO_2 for the sensor is reported in Fig. 3.

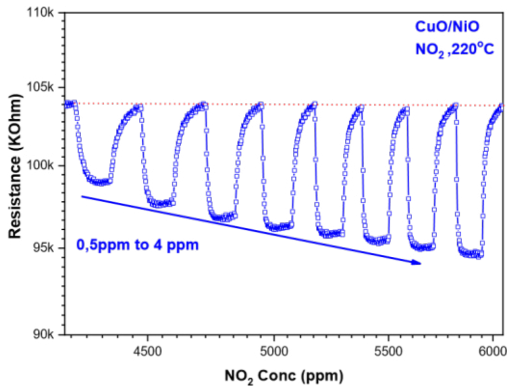

Fig. 3. Transient response of CuO/NiO hybrid sensors to different concentrations of NO_2 at the optimal temperature of 220 ◦C.

Conclusions

In summary, this study demonstrate that CuO/NiO nanocomposites demonstrates promising use for H_2 and NO_2 sensing. In addition, the dual selectivity of CuO/NiO hybrid sensor towards H_2 and NO_2 at two different temperatures was also demonstrated.

References

[1] Miller, D.R., S.A. Akbar, and P.A. Morris, *Nanoscale metal oxide-based heterojunctions for gas sensing: A review.* Sensors and Actuators B: Chemical, 2014. **204**: p. 250272.