DOI 10.5162/IMCS2018/P1GS.3

A low Temperature H_2 Gas Sensor Based on Pt-loaded Reduced Graphene Oxide/ZnO Nanocomposites

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Abstract

Platinum (Pt) loaded reduced graphene oxide (rGO)/zinc oxide (ZnO) nanocomposite were fabricated by using a combination of sputtering system and pulsed laser ablation in liquid method. The structure and morphology of the rGO/ZnO/Pt hybrid nanocomposites were characterized by field emission X-ray diffraction (XRD), Raman spectroscopy, and scanning electron microscopy (FESEM). The gas-sensing properties of the fabricated sensors were investigated for hydrogen (H_2) at different operating temperatures. The obtained rGO/ZnO/Pt ternary composite exhibits outstanding sensing response towards H_2, almost 7.5 times and 3.0 times higher than that of pure ZnO and ZnO/rGO, respectively. These results show that the combination of noble metals nanoparticles with rGO and ZnO can impart new gas sensing functionality that is potentially useful for H_2 sensing applications.

Key words: H_2 sensors, nanocomposite, reduced graphene oxide, zinc oxide, platinum.

Introduction

Hydrogen (H_2) is considered as one of the widely used energy source in aeronautical, industrial, agricultural and military fields, However, H_2 is an extremely dangerous gas for its flammable and explosive nature, and prone to leakage due to its low viscosity. Thus, there is a demand for highly sensitive H_2 gas sensor. Metal oxide gas sensors such as ZnO, SnO_2, and WO_3, are known as popular H_2 sensors. However, they are working at high temperature with low response and long response and recovery time. Graphene, noble metals, and reduced graphene oxide (rGO) are used as an ideal choice for loading onto other materials like metal oxides, and metal sulphides to improve their sensing performance. Several methods were used to fabricate different types of nanocomposites for H_2 sensing applications. In this work, pulsed laser ablation in liquid (PLAL) method was used to fabricate rGO/ZnO nanocomposite and sputtering system was utilized to load thin layer of Pt onto the surface of the rGO/ZnO nanocomposite for H_2 sensing applications.

Experimental work

Preparation of the ternary hybrid device structure employing ZnO, rGO and Pt included four steps, (i) ZnO nanoparticles were fabricated using PLAL as described in our previous work [1], (ii) Hummers' method was used to prepare GO nanosheets [2], (iii) 1%rGO/ZnO nanocomposite was fabricated using pulsed laser ablation of ZnO and GO in deionized water for 40 minutes, and (iv) DC sputtering system was employed to deposit a thin layer of Pt onto the surface of the rGO/ZnO nanocomposite using sputtering power of 30 watt for 30 second. Details of sensor design, and sensing system are provided in our previous study [3].

Results and discussion

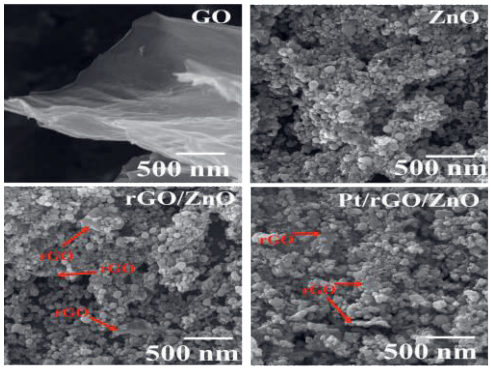

Fig. 1. FESEM images of GO, ZnO, rGO/ZnO, and Pt loaded rGO/ZnO nanocomposite.

Fig. 1 shows the FESEM images of the fabricated materials. Growth of long-nanosheets, and nanoparticles with various sizes are clearly observed in the GO and ZnO samples, respectively. It is obvious that the rGO/ZnO nanocomposite inhibited the morphology of both pure rGO and ZnO samples. Both Raman and XRD analyses (not shown) confirm the formation of the rGO/ZnO and Pt/rGO/ZnO nanocomposites.

Fig. 2 displays the gas sensing properties of the fabricated sensors. The response of the sensors was calculated using the following formula:

$$\text{Re}\,sponse\ (\%) = \frac{R_0 - R_g}{R_o} \times 100$$

where R_0 and R_g are the resistance of the sensors in air and H_2, respectively.

The influence of operating temperature on the response was studied for 400 ppm H_2 in the temperature ranging from RT to 180 ºC.

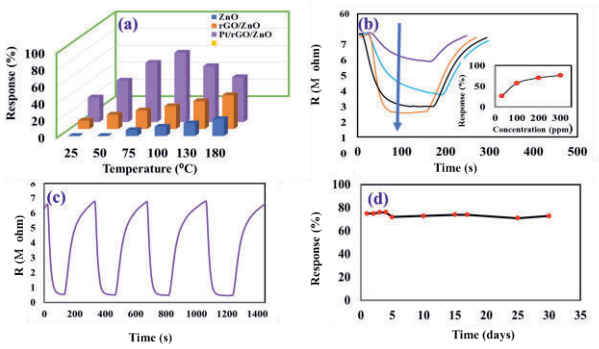

Fig.2. (a) The responses of ZnO, rGO, and Pt/rGO/ZnO sensors to 400 ppm H_2 at different working temperatures (b) the response of the Pt/rGO/ZnO sensor to various H_2 concentrations at optimal working temperature of 100 °C, (c) and (d) repeatability and long-term stability of Pt/rGO/ZnO gas sensor to 400 ppm H_2 at 100 °C, respectively.

As can be seen from Fig. 2(a), the response of the Pt/rGO/ZnO sensor is higher than that of ZnO sensor and rGO/ZnO sensor at all operating temperatures. The optimal operating temperature for achieving the maximum H_2 response for the Pt/rGO/ZnO sensor was obtained at 100 ºC. Fig. 2(b) shows the dynamic response curves of the Pt/rGO/ZnO sensor as a function of time towards 30 ppm, 100 ppm, 200 ppm, and 300 ppm H_2 at 100 ºC. It can be observed that the resistance of the sensor increases rapidly when low concentrations of H_2 are introduced. Upon removing the H_2, the sensors' resistance recovers to its initial value, indicating the complete recovery of the sensor. The response of the Pt/rGO/ZnO sensor as the H_2 gas sensor increase form 26 at 30 ppm to 76 at 300 ppm (inset).

Fig. 2(c) shows a good repeatability of the Pt/rGO/ZnO sensor response to 400 ppm H_2 at working temperature of 100 ºC. Fig. 2(d) shows the gas sensing response to 400 H_2 at 100 ºC within one month. It can be clearly seen that the response of the Pt/rGO/ZnO sensor was stable within a range of 3% confirming the long-term stability of the fabricated sensor.

Acknowledgment

The authors would like to acknowledge the support provided by the Deanship of Scientific Research (DSR) at King Fahd University of Petroleum & Minerals (KFUPM) for funding this work through project No.SR171005.

References

[1] M.A. Gondal, Q.A. Drmosh, Z.H. Yamani, T.A. Saleh, Synthesis of ZnO_2 nanoparticles by laser ablation in liquid and their annealing transformation into ZnO nanoparticles, Appl. Surf. Sci. 256, 298–304 (2009); https://doi.org/10.1016/j.apsusc.2009.08.019.

[2] W.S. Hummers, R.E. Offeman, Preparation of Graphitic Oxide, J. Am. Chem. Soc. 80, 1339–1339 (1958); doi: 10.1021/ja01539a017.

[3] Q.A. Drmosh, Z.H. Yamani, M.K. Hossain, Hydrogen gas sensing performance of low partial oxygen-mediated nanostructured zinc oxide thin film, Sensors Actuators, B Chem. 248, 868-877 (2017); https://doi.org/10.1016/j.snb.2017.01.082

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