CARBON DIOXIDE GAS SENSING APPLICATION OF GRAPHENE/ Y_2O_3 QUANTUM DOTS COMPOSITE

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Graphene/ Y_2O_3 quantum dots (QDs) composite was investigated towards the carbon dioxide (CO_2) gas at room temperature. Graphene synthesized by electrochemical exfoliation of graphite. The composite prepared by mixing 20-wt% graphene into the 1 g Y_2O_3 in organic medium (acetone). The chemiresistor of composite prepared by screen-printing on glass substrate. The optimum value of sensing response (1.08) was showed by 20-wt% graphene/ Y_2O_3 QDs composite. The excellent stability with optimum sensing response evidenced for the composite. The gas sensing mechanism discussed on the basis of electron transfer reaction.

Keywords: Graphene, Y_2O_3 , quantum dots, CO_2 .

1. Introduction

Graphene incorporated composites materials have emerged as a new class of materials with interesting electron-transport behavior and a material with strong potential in technological applications. Their ease of synthesis together with their chemically tunable properties makes them especially useful in electronic, optoelectronic, and electromechanical devices [1]. Graphene is a promising candidate as gas sensing materials due to its functional morphology [2]. Cao et al [3] reported a cataluminescence sensor using Y_2O_3 nanoparticles as the sensing materials proposed for the determination of ethyl acetate. This ethyl acetate sensor showed high sensitivity and specificity at the optimal temperature of 264°C . The CO_2 is one of the most common gases evolved in the combustion responsible for increasing global warming. It is chemically stable oxidising gas. Therefore, strong sensing material required for detection of CO_2 concentrations [4].

In the present investigation, 20 wt% of graphene/ Y_2O_3 nanocomposite is investigated for CO_2 gas sensing. The materials are analyzed by ultraviolet-visible (UV-VIS) and transmission electron microscopy (TEM) analysis. The gas sensing response and stability of composite are studied at room temperature.

2. Experimental

Graphene was synthesized by the electrochemical exfoliation of graphite. The graphite flake was used as an anode and source of graphene. The silver electrode was used as a cathode. The graphite flake and silver electrode were inserted into the ionic solution with separation of 5 cm. AR-grade chemicals were used in this investigation for the preparation of ionic solution. The ionic solution was prepared by taking 4.8 g of sulphuric acid diluted in 100 ml [5]. Exfoliation process was carried out by DC bias arrangement (10 V). An exfoliated graphene was collected through cellulose nitrate filter paper and washed with double distilled water. The obtained sample was dried at 100 °C for 2 h. Commercial high-purity Y_2O_3 powder (SD-Fine) was used in the synthesis of composite. The graphene/ Y_2O_3 composite were prepared by mixing 20 wt% of graphene in constant 1 gm Y_2O_3 in 30 ml acetone as organic media. The solid-state chemiresistive method was adopted for gas sensing. The chemiresistor was prepared by screen-printing technique on chemically clean glass substrate. The silver electrode deposited on the both side of chemiresistor for resistance measurement. The electrical resistance was measured by using a voltage drop method adopted by Waghuley et al [6]. The CO_2 gas concentration inside the chamber was maintained by gas injecting method.

3. Results and discussion

The UV-VIS analysis was employed to know the optical properties of materials. It is straightforward technique to probe the optical band gap of material. Hence, imaging small structures through electron microscopy techniques is not enough to say it is in quantum confinement state [7] The UV-VIS spectra of graphene and Y_2O_3 displayed in Figs 1 and 2 respectively, inset shows their band gap. These values of band gap are used to compute the particle size of materials with the help of hyperbolic band model (HBM) [8]. As the band gap is particle size dependent, we can estimate the particle size. The particle size found to be for graphene and Y_2O_3 is 6.06 and 28 nm respectively.

Fig.1. UV-VIS spectra of graphene and inset shows the plot between $(h\nu)/(\alpha h\nu)^{1/2}$

Fig.2. UV-VIS spectra of Y_2O_3 and inset shows the plot between $(h\nu)/(\alpha h\nu)^{1/2}$

The TEM analysis was employed to study the morphology of material displayed in Fig.3 (a) and (b). Fig.3 (a) shows the TEM of graphene giving different levels of transparency. Fig 3 (b) shows the TEM of Y_2O_3 , showed particle are not perfectly spherical. The average stacking size of graphene sheet from TEM analysis found to be 8 nm. The average crystallite size of Y_2O_3 was found to be 30 nm. The average crystallite size found from TEM investigations are in agreement with UV-VIS analysis.

Fig.3. TEM of (a)graphene and (b) Y_2O_3

The gas sensing response of Y_2O_3 , graphene and 20-wt% of graphene/ Y_2O_3 composite depicts in Fig. 4. As the CO_2 is oxidizing, resistance increases with increasing concentration. The sensing response of graphene and 20-wt% of graphene/ Y_2O_3 composite shows the good dependence on the concentration of CO_2 gas. The gas sensing response value of Y_2O_3 attends saturation onwards 20 ppm. The optimum value of sensing response found to be 1.08 for 20-wt% of graphene/ Y_2O_3 composite at 35 ppm.

Fig.4. Sensing response of Y_2O_3 , graphene and 20-wt% of graphene/ Y_2O_3 composite

The stability characteristics of Y_2O_3 , graphene and 20-wt% of graphene/ Y_2O_3 composite were examined with 25 ppm concentration of CO_2 for 15 days at room temperature shown in Fig. 5. The chemiresistors shows almost constant response, indicating good stability.

Fig.5. Stability of Y_2O_3 , graphene and 20-wt% of graphene/ Y_2O_3 composite

Gas sensing action basically depends on electron transfer reactions, which are redox reactions. In this reactions the electron donor is oxidised and the acceptor reduced. The basic assumption of the theory is a weak electronic interaction of the two reacting species is required for a simple electron transfer process to occur. The reactants may be ions or molecules. The free energy that drives the reaction is the difference in reduction potentials between donor and acceptor [9]. The gas-sensing mechanism based on the surface reaction between the adsorbed oxygen ions and the gas molecules. Oxygen may

be either physisorbed as uncharged molecules or chemisorbed as charged species on the surface of material. As the CO_2 having tendency to withdrawing electron from the surface, electrical resistance of material increase.

4. Conclusions

The synthesized graphene/ Y_2O_3 QDs composites possess good gas sensing response and stability at room temperature. The particle size determined from UV-VIS and TEM analysis are in agreement. The morphological study pointed out that the graphene and Y_2O_3 surface functional for gas sensing application. The optimum value of sensing response was found to be 1.08 for 20-wt% of graphene/ Y_2O_3 QDs composite.

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