Liquefied Petroleum Gas Sensing Application of ZnO Quantum Dots Loaded Graphene Composite

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Abstract

In the present study, we prepared the 50 wt.% ZnO quantum dots loaded graphene composite for resistive gas sensing application towards the liquefied petroleum gas (LPG). ZnO quantum dots loaded graphene composite was characterized through X-ray diffraction, Scanning electron microscope, Ultraviolet–visible spectroscopy and Raman spectroscopy. The 50 wt.% ZnO-graphene composite based resistive sensor exhibits good LPG sensing properties at room temperature. The sensor exhibits operating temperature around 423 K. Moreover, sensor exhibits the good stability for one month, and fast response (12 s) and recovery time (22 s).

Keywords- Liquefied petroleum gas; Quantum dots; Graphene.

Introduction

Detection of highly inflammable gases like liquefied petroleum gas (LPG) at low concentration is very crucial for safety requirements in industries and household applications. Therefore, LPG sensing is necessary and many reports on LPG show that its efficient detection is possible by graphene [1, 2].

Singh et al studied the CO, NH_3 and NO gas sensing response of low concentrations of the order of 1 ppm at room temperature. This study demonstrated that gas sensor response and quick recovery time was observed at room temperature with good selectivity towards electron donor gas that is CO and NH_3 [3]. Khenfouch et al reported the ability of graphene-ZnO based composite for hydrogen sensing. In this study, graphene and nanostructured ZnO used to analyzed optoelectronic properties especially for gas sensing applications [4]. Liu et al reported the NO2 gas sensing performances of reduced graphene oxide-ZnO nanoparticles hybrids at room temperature. As-fabricated sensor exhibits higher sensitivity, shorter response time and recovery time than those of the sensor based on reduced GO. NO_2 sensing operating at room temperature enhanced with the addition of ZnO nanoparticles [5]. Zou et al demonstrated the ZnO nanorods on reduced graphene sheets as a multifunctional material for various application such as field emission, gas sensor and photocatalytic properties. Due to the exceptional mechanical and electrical properties of ZnO-graphene were demonstrated for excellent field emission properties. Similarly, sandwich like ZnO/G/ZnO heterostructures have much higher photocatalytic activity under UV irradiation than those of ZnO nanorods and ZnO/graphene heterostructures [6].

In the present work, we demonstrated the LPG sensing application of ZnO quantum dots loaded graphene composite. The various gas sensing parameters were determined and discussed in this paper.

Experimental

In the present work, 50 wt.% ZnO quantum dots loaded graphene composite was used for LPG sensing application. Synthesis of ZnO quantum dots loaded graphene composite is explained in our previous Ref. [7]. The specification of analytical tools and gas sensing assembly is provided in the Ref. [8].

Results and Discussion

Figure 1 shows the XRD pattern of ZnO quantum dots loaded graphene composite and inset shows SEM image. XRD pattern shows broad hump in 2θ range 20-30°, which associated with (002) plane of graphene. This is characteristics peak of graphene. Besides that XRD pattern comprises some sharp peaks which reflect the good incorporation of ZnO QDs into graphene. This directly visualized from the SEM image (Inset of Figure 1). SEM image shows that ZnO QDs nicely anchored on graphene surface.

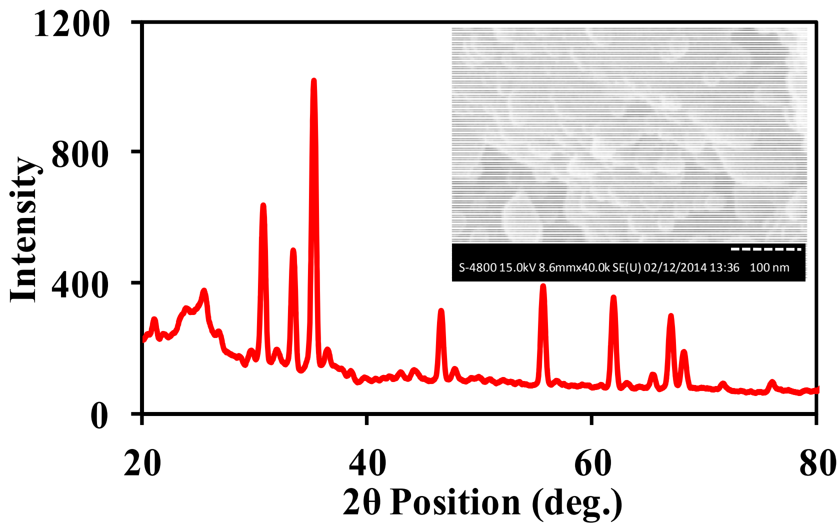

Figure 1. XRD pattern of ZnO quantum dots loaded graphene composite
and inset shows SEM image.

Figure 2 shows the UV-VIS spectrum of ZnO QDs loaded graphene composite collected in wavelength range 200-500 nm. It is observed that sample shows intense absorption tail around 390 nm. UV-VIS analysis shows that quantum confinement characteristics of ZnO QDs diminish in composite state [9]. Inset of Figure 2 shows that Raman spectrum of as-prepared composite. It is directly noticeable that typical spectra of graphene not affected strongly. The position of D and G band does not affected in synergetic state of composites.

Figure 3 depicts the LPG sensing response of ZnO quantum dots loaded graphene composite at room temperature (303 K). The gas sensing response shows good dependence on the LPG concentration. This can verify from response curve, which is almost linear (R2=0.99). Inset of Figure 3 shows the operating temperature response of as-prepared composite for 50 ppm LPG. It is observed that sample shows optimum gas sensing response towards LPG at 423 K, which is much below the auto-ignition temperature of LPG.

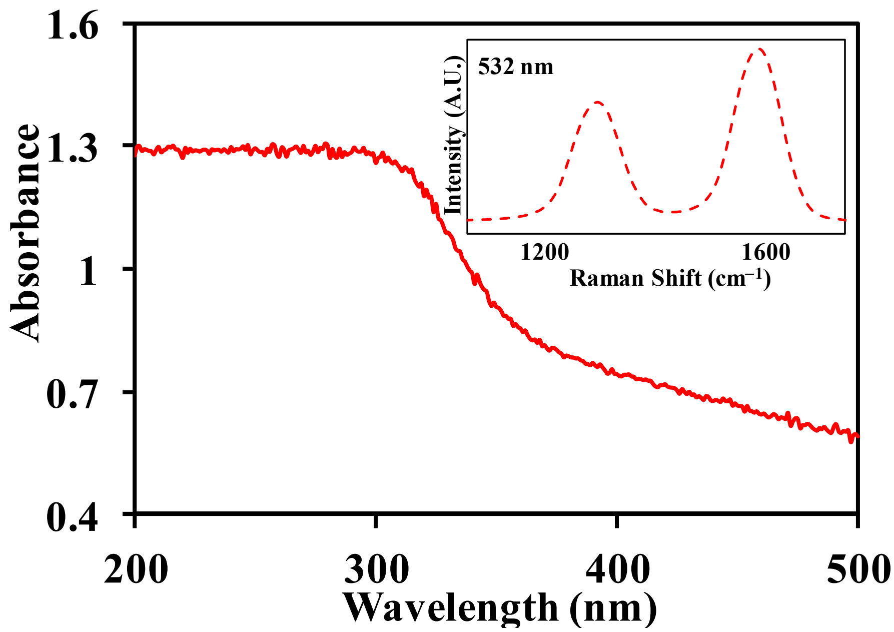

Figure 2 UV-VIS spectra of ZnO quantum dots loaded graphene composite and inset shows Raman spectra.

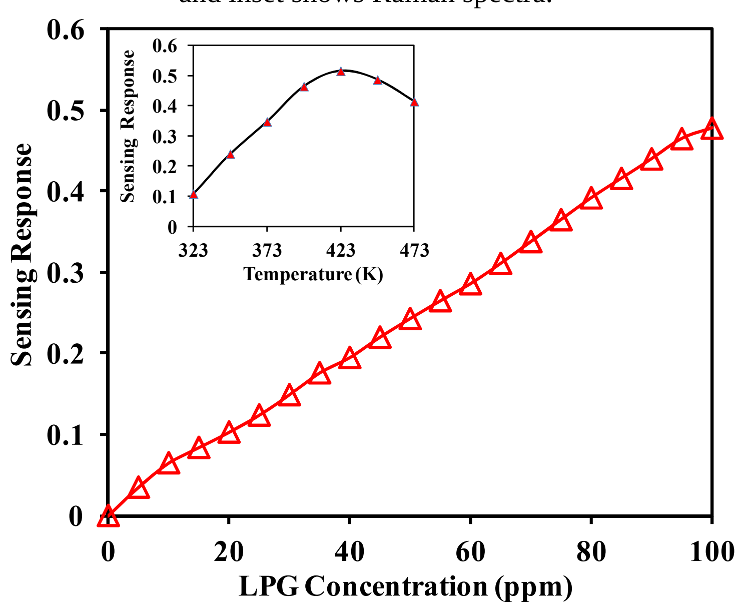

Figure 3 LPG sensing response of ZnO quantum dots loaded graphene composite and inset shows operating temperature response.

Figure 4 shows the stability performance of ZnO QDs loaded graphene composite and inset shows transient response curve towards the 100 ppm LPG at room temperature. The as-prepared composite shows good stability for one month. The transient response curve shows that sensor exhibits fast response (12 s) and recovery time (22 s) characteristics.

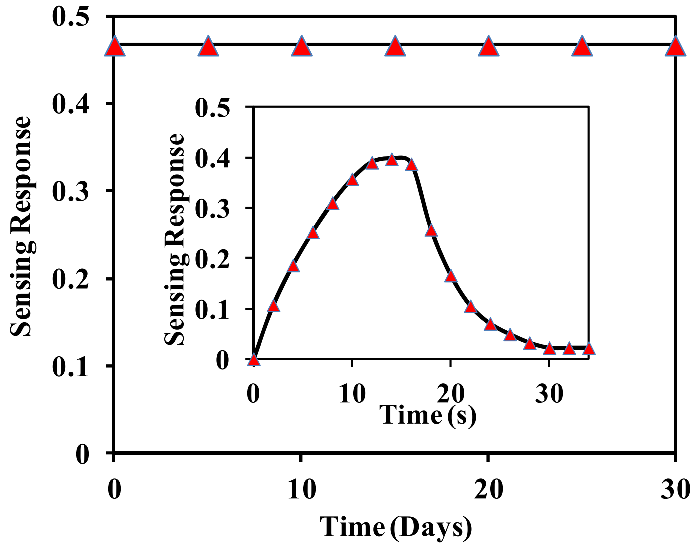

Figure 4. Stability performance of ZnO quantum dots loaded graphene composite and inset shows transient response.

Conclusions

In the summary, we successfully demonstrated LPG sensing application by ZnO quantum dots loaded graphene composite. The as-prepared sample shows good sensing and operating temperature response. The operating temperature value was found to be 423 K. The sample shows fast response and recovery time characteristics. The main achievement of present work is low operating temperature, which is much below auto-ignition temperature of LPG.

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