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Different strategies for fabrication of rGO-SMO based nanocomposites

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Abstract

Due to its excellent electronic properties, graphene-based materials have been explored for a different range of applications [1]. More recently, several research groups have been developing new strategies to enhance and finely tune its physical properties by decorating the graphene sheets with other nanostructured materials [2][3]. In the present study, we propose and compare different experimental procedures to fabricate reduced graphene oxide (rGO) and ZnO metal oxide (SMOx) nanoparticles composite. Graphene oxide films were prepared by the modified Hummers method and reduced by a physical approach using a UV nanosecond pulsed laser and a traditional chemical route. ZnO was synthesized by the polymeric precursor method. Three methodologies were used to produce the composites which were characterized by Raman, XPS and SEM techniques.
Keywords: graphene oxide, rGO/ZnO composites, gas sensors.

Introduction

Graphene is a two-dimensional material that consists of a single layer of hybridized sp^2 carbon atoms forming a hexagonal network arranged in the form of honeycombs[1]. Due to its excellent electronic and mechanical properties such as high electrical and thermal conductivity, high transport mobility, it is considered a promising material for applications in solar cells, transistors, gas sensors, among others[2].

Several routes have been used to obtain graphene, one of the most used routes is the oxidation of graphite through the modified Hummers method to get graphene oxide (GO), followed by a reduction process to obtain reduced graphene (rGO), which recover the electronic properties of the pristine material [3][4].

Several groups reported the use of gas sensors based on pure rGO; however, these sensors presents low sensitivity, long response and recovery times [5]. Therefore, several efforts have been developed to optimize these sensors through the decoration or functionalization of the rGO surface with semiconductor metal oxides [6]. Among them, rGO/ZnO sensors exhibited notable characteristics, as ZnO is a suitable electron donor and rGO is a good electron acceptor [5].

Thus, the objective of the present work is the development of a fast and low-cost methodology to produce rGO/ZnO composites for application as gas sensors.

Experimental Procedure

Synthesis of GO, rGO and ZnO

GO was synthesized using the modified Hummers method [7]. rGO films were obtained when GO film was exposed to an laser radiation . The irradiation was obtained from a Nd:YAG laser with a wavelength of 266 nm, a spot size of 5 mm

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and fluence of 100 mJ/cm^2. ZnO was synthesized by the polymeric precursor method [8].

Production of rGO/ZnO Composites

The rGO/ZnO composites were produced by three different methodologies. In the first methodology, a solution formed by ZnO diluted in acetone (1.5 mg/ml) was deposited via drop-casting onto the surface of rGO film. In the second methodology, the same ZnO solution was deposited via drop-casting onto a GO film surface and then the GO was reduced by laser radiation. In the third methodology, a commercial rGO in solution (2 mg/ml) was used. A commercial rGO solution was mixed with a ZnO solution (20 mg/ml) in a 1:7 ratio and deposited via drop-casting onto a Si substrate.

Results and Discussion

Figure 1 shows the Raman spectra of rGO/ZnO composite materials. It can be observed that the composites spectra using methodology 1 and 3 present the main bands referring to rGO, between 1000 and 3500 cm-1, and at lower frequencies, the peaks referring to ZnO. On the other hand, in the composite obtained by methodology 2, there are regions that present only the expected bands for the rGO and regions that present the bands and peaks of both materials, suggesting that this rGO/ZnO film is not homogeneous.

Table 1 presents the concentrations (in % at) of the elements present in the three composites obtained by the analysis of the XPS survey spectra. All composites have the expected elements carbon, oxygen, zinc. Furthermore, it was also detected in some films small concentrations of silicon that is related to the substrate. In the composite with commercial rGO a small concentration of sodium was detected, which is related to the chemical reduction used. No contamination was identified in the samples.

Figure 1 - Raman spectrum of rGO/ZnO composites.

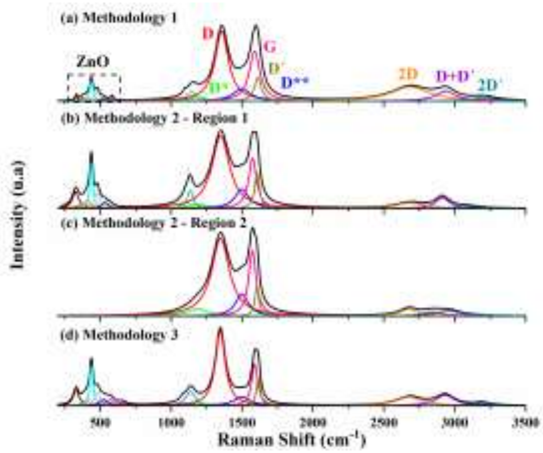
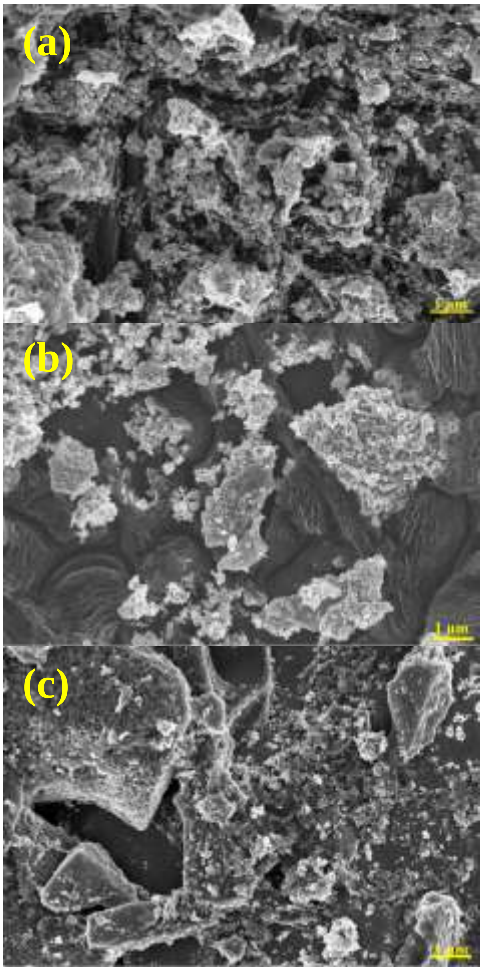


Table 1 - Composition (% at) of elements detected in the XPS survey spectra of rGO/ZnO composites.

Methodology	C	O	Zn	Si	Na
1	80,9	10,6	0,5	8,0	-
2	78,8	14,1	0,3	6,8	-
3	71,6	24,4	1,9	-	2,0

Figure 2 shows the SEM images of the composites. Figure 2 (a) shows the expected periodic and porous structure of rGO and that ZnO nanoparticles are homogeneously distributed over the material surface. Figure 2(b) also shows the porous periodic structure of rGO, however, ZnO nanoparticles are forming aggregates on the composite surface, in agreement with Raman results. Figure 2 (c) shows that the composite no longer presents a porous periodic structure, as the rGO was chemically reduced. As a solution containing rGO and ZnO was used in this methodology, the composite presents the ZnO nanoparticles wrapped in rGO sheets.

Figure 2 – SEM images of the composites obtained by methodologies (a) 1, (b) 2 and (c) 3.



Conclusions

We can conclude that it was possible to obtain the rGO/ZnO composites through the developed methodologies. Among the composites, those with the most homogeneous films were those prepared by methodology 1 and 3. The films from methodology 2 formed ZnO agglomerates.

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