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Investigations on structural, optical and electrical properties of microwave-assisted rGO:ZnO nanocomposite thin films

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Abstract

The reduced graphene oxide:Zinc oxide (rGO:ZnO) nanocomposite films were fabricated by an optimized wet-chemical sol–gel derived spin-coating method. A simple, fast and effective microwave-assisted approach was adopted for the reduction of the graphene oxide. The influence of rGO on the microstructural and optoelectronic properties of ZnO was studied by varying the weight ratios of rGO. The results showed significant changes in the microstructural and optoelectronic properties of the rGO:ZnO composite films. X-ray diffraction analysis confirmed the polycrystallinity of the composite films with a preferential growth orientation of the crystallites along (002) plane. Good optical transparency in the visible wavelength region was observed in all the composite films. As the weight percentage of rGO increased from 0% to 20%, the red shift of the absorption edge was noticed, indicating the weak Burstein-Moss effect. The optical bandgap of ZnO reduces as the amount of rGO increases, resulting in the reduction of transmittance in the composite thin films. The sheet resistance and therefore the resistivity of the composite films decreases with the loading of rGO into ZnO matrix. The lowest values of sheet resistance and resistivity, and the highest Figure of Merit have been recorded for 10% rGO:ZnO composite film. The obtained results illustrate that the 10% rGO:ZnO composite film could be a potential candidate for electrode applications.

Introduction

Metal oxide nanomaterials with diverse compositions and rich features play a significant role in the environment and energy fields. Among them, zinc oxide (ZnO) seems to be a very promising material and is extensively studied due to its intriguing properties, which include a stable chemical structure, low cost, a direct energy wide band gap (3.37 eV), high chemical and thermal stability and its large exciton binding energy (60 meV). ZnO is widely used as transparent electrodes in optical and electrical devices such as organic light-emitting diodes (OLEDs), touch display panels, sensors, and solar cells [1], [2], [3], [4]. Several studies have shown that ZnO doped with few elements improves its mobility, optical and magnetic properties, donor and acceptor defects and conductivity [5], [6]. Further, several efforts have also been made to modify the properties of ZnO by making composites with graphene oxide (GO) and reduced graphene oxide (rGO) to enhance the performance of the film for device application [7], [8], [9], [10]. GO is a one-atom-thick planar sheet consisting of hydroxyl and epoxide groups on its basal plane and carboxyl groups on its edges which results in a hybrid carbon structure with a mixture of sp^2 and sp^3 hybridized carbon atoms. The presence of the functional groups in graphene oxide also makes it a very chemically active material and facilitates energy gap manipulation by simple chemical methods [11]. Moreover, the hydrophilic nature of GO enables it to form a stable and homogeneous dispersion in various organic solvents as well as in water [12]. For the reduction of GO, chemical, thermal, optical, and hydrothermal approaches have been used. Recently, the microwave reduction technique has become a feasible nonchemical reduction technique since microwave heating depends on the penetration of waves and the absorption characteristics of the material. This method is more viable in solid-phase reactions because the substance can be heated uniformly and effectively without wasting energy on mechanical stirring. In the present work, the GO is reduced by a microwave-assisted approach and the composite films of rGO:ZnO was fabricated using an optimized sol–gel spin-coating method and the role of rGO on the structural and optoelectronic properties of ZnO films was explored.

Section snippets

Preparation of GO and rGO

A modified Hummer's method was used to prepare GO from the natural graphite powder (98%) purchased from SDFCL. For the synthesis, 1 g of the natural graphite powder was added into a 250 ml conical flask along with conc. H_2SO_4 (98% pure from Merck Chemicals). Then, $KMnO_4$ (98% - Merck Chemicals) was gradually added while being stirred in an ice bath to avoid overheating and explosion. The mixture was diluted by adding 150 ml of distilled water after being stirred on a magnetic stirrer for 6 h at…

Structural study

The crystalline structure of pure ZnO and rGO:ZnO composite films were investigated using XRD. Fig. 1 shows the diffractogram of ZnO and rGO:ZnO composite films for different percentages of rGO. All the composite films exhibit significant diffraction peaks corresponding to (100), (002) and (101), showing that the ZnO thin films are polycrystalline and have a hexagonal wurtzite structure (JCPDS File No. 36–1451, a=b=3.249 Å, c=5.206 Å). However, after introducing rGO into the ZnO matrix,…

Conclusion

In summary, the rGO:ZnO composite thin films were fabricated on a glass substrate using a cost-effective, sol–gel derived, spin coating technique. A simple, fast and effective microwave-assisted approach was used for the reduction of the graphene oxide. The XRD studies showed the polycrystallinity of the rGO:ZnO composite thin films with hexagonal wurtzite crystal structure and confirmed the preferable c-axis orientation of the crystallites. Pure ZnO thin film exhibits the highest optical…

CRediT authorship contribution statement

N. Rashmi: . **F.J. Serrao:** . **V.S. Kindalkar:** . **K. Kumara:** . **N.B. Rithin Kumar:** . **M.B. Savitha:** . **Joyline G. D'sa:** Formal analysis, Investigation, Methodology, Writing – review & editing.…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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