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Optical, photocatalytic, electrochemical, and magnetic applications of co-precipitation-assisted ZnO@graphite nanocomposites

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ABSTRACT

In the current study, ZnO@graphite nanocomposites were synthesized using an easy co-precipitation route to develop multifunctional properties suitable for assessing energy storage, optoelectronic, photocatalysis, and magnetic applications. Structural characterizations (XRD, SEM, TEM, EDX, and XPS) of the synthesized composite confirmed the strong interfacial interaction between the ZnO and graphite composite with good crystallinity and composed of heterogeneous particle morphology. Nitrogen adsorption–desorption studies demonstrated a mesoporous structure. The UV–visible spectrum of ZnO@graphite showed a strong ultraviolet absorption edge at 370 nm as well as confirming the band gap value to be 3.06 eV. Visible luminescence peaks were detected in the recorded PL spectrum of the ZnO@graphite, which is caused by the presence of oxygen vacancies and interfacial defects. The photodegradation performance of three different dyes (Acridine orange (AO), Congo red (CR), and Alizarin red (AR)) along with the synthesized composite as a photocatalyst under the illumination of UV light was comparatively discussed in detail. Among the dyes, acridine orange was found to be effective for photodegradation efficiency (99.8%) with shorter time intervals (150 min) than the other two dyes (Congo red (95.8%) for 180 min and Alizarin red (51.9% for 210 min)). Electrochemical property response (oxidation/reduction, specific capacitance and electrical transport) of the ZnO@graphite at various scan rates (10–200 mVs^{-1}) were scrutinized with the assistance of cyclic voltammetry and electrochemical impedance measurement. The electrochemical measurement results demonstrated pseudocapacitive behaviour. Using PPMS measurement, the synthesized nanocomposite confirmed a weak ferromagnetic behaviour at room temperature.

1. Introduction

Numerous researchers attempted to synthesize and select a single compound of nanomaterial that can perform the multi-functional properties for the increasing demand to develop energy storage devices, optoelectronics, photocatalysis, and magnetism applications [1–5]. Particularly, carbon-based material admixture with the metal oxide nanocomposites is one of the materials that have gained considerable much attention in the multi-functional device applications [6]. When carbon-based materials are combined with transition metal oxides, effectively involving electrochemical activity, excellent electrical conductivity, mechanical stability, chemical inertness, free electron movement, etc. Especially, allotropes of carbon admixture on the zinc oxide with nano-dimension formation have proved to have better catalytic and optical response features and excellent electrochemical sensing, as well as act as biomaterials, according to our recent earlier reports and those of other researchers [7–28].

Zinc oxide (ZnO) is widely used as a semiconductor material because of its wider band gap (~3.37 eV), good thermochemical stability, and strong ability to absorb ultraviolet light. It also shows visible light emission due to the presence of defects, which makes it useful for unique optoelectronic applications such as light-emitting devices, photodetectors, and sensors [29]. Importantly, ZnO nanomaterials can undergo an oxidation and reduction in the photodegradation reaction and

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