SYNTHESIS AND CHARACTERIZATION OF TIO2-GRAPHENE QUANTUM DOTS NANOCOMPOSITES BY ELECTROCHEMICAL PROCESSES UTILIZING GRAPHITE RODS

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Abstract

Titanium dioxide (TiO_2) is a highly stable semiconductor known for its exceptional optical and electrical properties. However, its efficiency is often limited by the high recombination rate of electron-hole pairs. To improve its optical properties, TiO_2 can be integrated with graphene quantum dots (GQDs)—carbon-based nanomaterials exhibiting strong photoluminescence and high chemical stability. This research aims to investigate the physical and optical properties of TiO_2QDs/GQDs nanocomposites and examine the influence of the applied voltage during synthesis on these properties. The composites were synthesized via an electrochemical process using an electrolyte solution of 0.3 M potassium chloride and 0.1 M citric acid. The applied voltage was set at 10V for pure TiO_2, while varying voltages of 2V, 4V, and 6V were used for the TiO_2QDs/GQDs mixtures. The results indicated that the pH of the resulting solutions remained within the range of 2–3. UV–Vis spectroscopy analysis revealed an energy band gap ranging from 3.57 to 3.65 eV. Photoluminescence (PL) analysis clearly demonstrated the enhanced luminescent behavior of the nanocomposites. Furthermore, Dynamic Light Scattering (DLS) analysis showed that the TiO_2/GQDs synthesized at 6V exhibited an average hydrodynamic size of 111.00 nm. This reduction, compared to that of pure TiO_2 135.09 nm, indicates enhanced ion packing density on the particle surface. These findings suggest that the applied voltage plays a critical role in controlling particle size and material properties, which can be tailored by varying the voltage for specific applications.

Introduction

Titanium dioxide (TiO_2) is a highly stable semiconductor widely utilized in optoelectronics. However, its wide band gap restricts light absorption to the UV spectrum and leads to rapid electron-hole pair recombination, thereby reducing its optical properties. To address these challenges, this research proposes the fabrication of TiO_2/Graphene Quantum Dots (GQDs) nanocomposites. GQDs act as efficient electron acceptors and transporters, effectively suppressing charge recombination and extending light absorption into the visible spectrum. The nanocomposites were synthesized via a simple and cost-effective electrochemical process. The structural characteristics and optical properties were further investigated using Photoluminescence (PL) spectroscopy, UV-Visible spectroscopy, and Dynamic Light Scattering (DLS).

Methodology and Materials

1. simple preparations

First, the synthesis of TiO2 quantum dots was conducted in critric acid 0.1 M mixed in an electrolytic solution of KCl with concentration of 0.3 M mixed and dissolved in deionizing water (DL water). Titanium rods were used as electrodes as illustrated in figure 1a. A DC power supply of 15 V was used for 5 minutes, and the current was reduced to 10 V for 30 minutes. Then, Titanium rods were replaced by graphene rods. A DC power supply of 2 V, 4V and 6 V for 1 hour. After that, the solution of TiO2/GQDs in figure 1b.

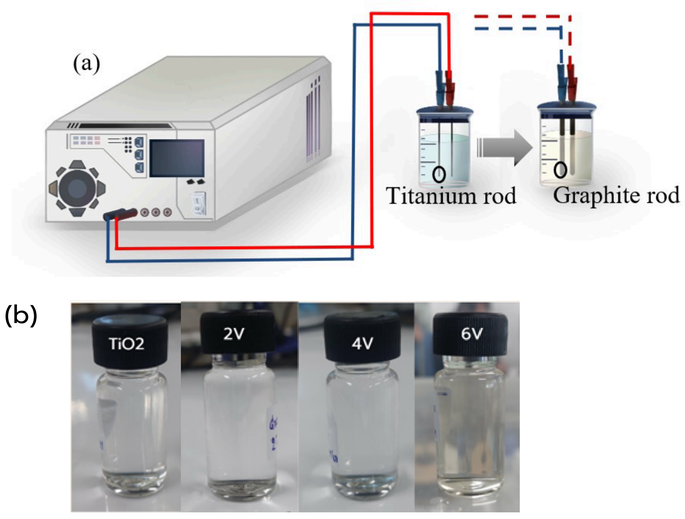


Figure 1 (a) Schematic diagram of TiO2/GQDs nanocomposites synthesized using solution-based electrochemical process. [1] *(b) The obtained solution after finished the process.*

2. Sample characterization

The TiO2/GQDs were characterized by UV-vis, photoluminescence (PL) with using Ocean Optics hardware setup with Deuterium light source, dynamic light scattering for particle size analysis

Conclusions

The results indicated that the pH of the resulting solutions remained within the range of 2–3. UV–Vis spectroscopy analysis revealed an energy band gap ranging from 3.57 to 3.65 eV. Photoluminescence (PL) analysis clearly demonstrated the enhanced luminescent behavior of the nanocomposites. Furthermore, Dynamic Light Scattering (DLS) analysis showed that the TiO_2/GQDs synthesized at 6V exhibited an average hydrodynamic size of 111.00 nm, which is significantly smaller than that of pure TiO_2 135.09 nm. These findings suggest that the applied voltage plays a critical role in controlling particle size and material properties, which can be tailored by varying the voltage for specific applications.

References

[1] Siripatsorn Thanasanvorakun *et al 2023 J. Phys.: Conf. Ser. 2653 012058*

Results

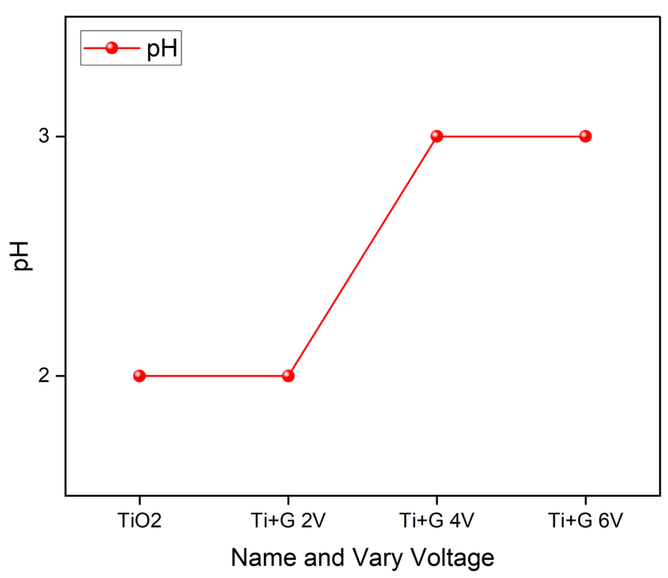


Figure 2 pH of electrolyte solution synthesized by electrochemical process.

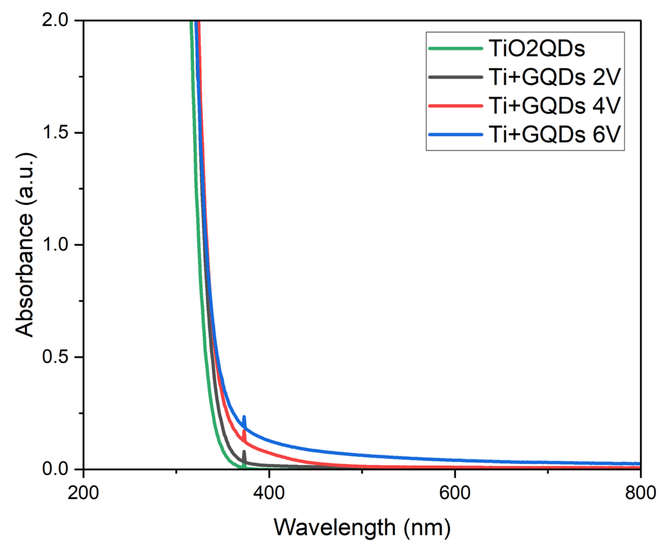


Figure 3 Absorbance of sample for each condition using UV-Vis Spectroscopy analysis

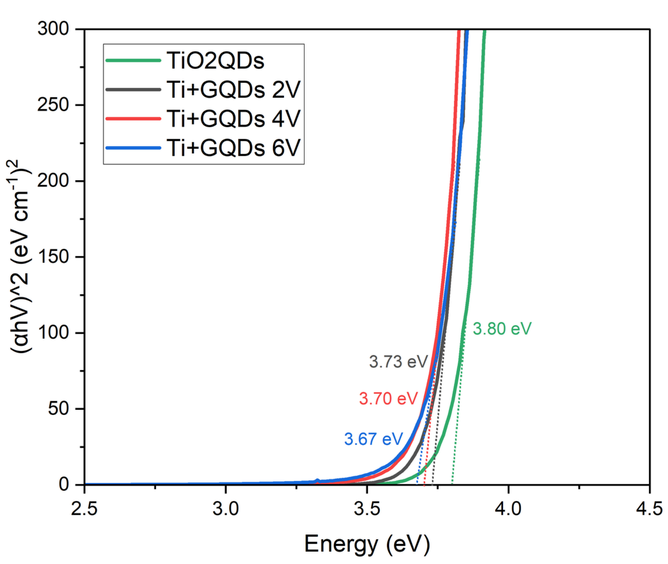


Figure 4 band gap of TiO2/GQDs is shown from UV-visible spectroscopy. TiO2/GQDs have a narrower energy gap as the current increases, which is narrower than TiO2QDs.

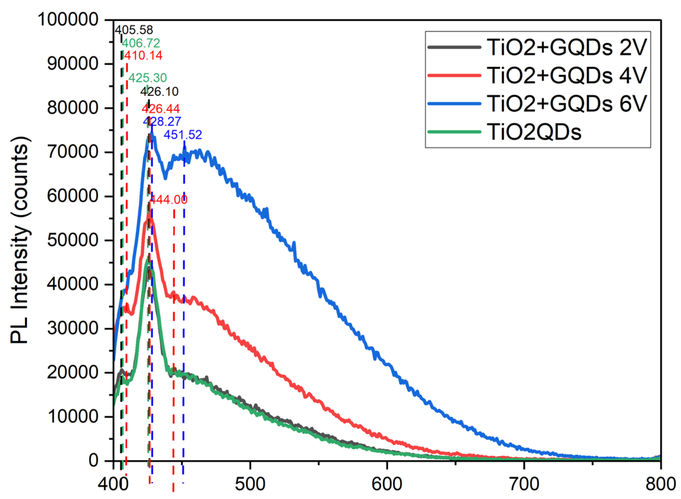


Figure 5 Paek PL spectrum of TiO2/GQDs and TiO2 QDs for A DC power supply of 2 V, 4V and 6V.

Figure 6 Schematic representation of the proposed energy levels of TiO2QDs and TiO2/GQDs The intrinsic state depends on size. The defect states and trap states determine the optical properties.

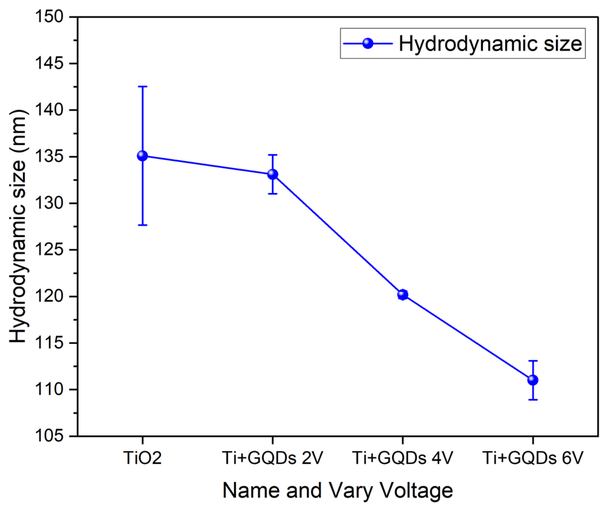


Figure 7 Hydrodynamic size of particle using dynamic light scattering analysis. Than can be seen that the hydrodynamic size decreases when the voltage is increased.