

Enhanced Fluorescence Behavior and Surface Characteristics of ZIF-8 Structures Modified with Graphitic Quantum Dots

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Abstract

In recent years, with the development of nanotechnology, the synthesis of new generation materials has become a focus of great interest. Graphitic quantum dots (GQDs) have attracted significant attention in various fields such as sensors, optoelectronic devices and biomedical applications due to their excellent optical properties, large surface areas, high photoluminescence efficiency and chemical stability [1]. These properties make GQDs promising for a wide range of scientific and industrial applications including biosensors, energy conversion and drug delivery. Metal-organic frameworks (MOFs) are widely used in applications such as gas storage, catalysis, drug delivery and separation technologies due to their high surface areas, regular porous structures and chemical flexibility [2]. Among these, zeolitic imidazolate framework (ZIF-8) stands out due to its high thermal and chemical stability. However, the optical properties of ZIF-8 are limited and enhancing its fluorescence properties is important for sensor and optoelectronic applications [3].

GQDs, with their small sizes, high photoluminescence efficiency, and chemical stability, can modify the optical and surface properties when integrated into MOF matrices. ZIFs (zeolitic imidazolate frameworks), known for their porous structures and chemical stability, are a class of MOFs used in various applications such as gas storage, separation, and catalysis. The combination of GQDs and ZIF-8 structures is significant in enhancing fluorescence properties and improving surface characteristics. In this context, rendering ZIF-8 structures fluorescent through GQDs and investigating their absorbance properties presents an important approach for the development of potential applications. Evaluating the effects of GQD integration into ZIF-8 structures on fluorescence properties also highlights the importance of characterizing surface features. The integration of GQDs into ZIF-8 structures not only reveals their fluorescence properties but also enables the arrangement of active groups on their surfaces. The interaction between GQDs and ZIF-8 not only improves optical properties but can also optimize the porous structure within the material, increasing its gas storage capacity [4].

This study aims to enhance the fluorescence properties of ZIF-8 structures using GQDs and to investigate their effects on surface properties. ZIF-8 structures were modified using GQDs, and the effects of this modification on their fluorescence properties were examined in detail. GQDs were synthesized via a microwave-assisted method using boric acid, urea, and varying amounts of citric acid. The microwave method offers high efficiency and low energy consumption, making it advantageous for controlled synthesis [5]. Varying the amount of citric acid demonstrated that the fluorescence behavior could be tuned by affecting the distribution of GQDs within the structure and their optical properties.

The synthesized GQDs were dissolved in methanol and incorporated into the ZIF-8 synthesis process. ZIF-8 structures were synthesized via controlled precipitation of 2-methylimidazole and zinc acetate dihydrate. The integration of GQDs into the ZIF-8 matrix and the resulting optical and structural changes were investigated. The obtained pure and GQD modified ZIF-8 structures were analyzed using various characterization techniques including Fourier transform infrared spectroscopy (FTIR), photoluminescence (PL), and UV-Vis spectroscopy.

FTIR analysis confirmed the existence of the ZIF-8 crystal structure. FTIR was used to determine changes in chemical bond structures. UV-Vis spectroscopy was used to evaluate the fluorescence properties. The characterization results showed that GQDs were successfully integrated into the ZIF-8 structure.

FTIR analyses confirmed that the characteristic vibration bands of imidazole groups were preserved in the GQD modified ZIF-8 structures. UV-Vis spectroscopy analyses showed that the fluorescence properties of ZIF-8 structures were significantly enhanced by the incorporation of GQDs. The fluorescence emission intensity can be controlled by changing the GQD concentration, which allows tunability in optical properties. This suggests that the modified structures may be suitable for sensor and optoelectronic applications. This study comprehensively investigated the changes in optical and surface properties of ZIF-8 structures modified using GQDs. The results showed that the incorporation of GQDs significantly

imparted fluorescent properties to ZIF-8. The findings highlight the potential of such hybrid materials to develop efficient adsorbents, photocatalysts, and luminescent probes. Non-fluorescent ZIF-8 structures were converted into fluorescent materials by this method. Such hybrid structures have broad application potential in sensor technologies, optoelectronics, and environmental pollutant removal. Future studies may focus on improving material properties using different combinations of GQDs and MOFs, allowing the investigation of selective adsorption mechanisms.

Keywords: Graphitic quantum dots, ZIF-8, fluorescence, surface properties, nanomaterials.

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