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Graphitic carbon nitride nanosheets coupled with carbon dots and BiOI nanoparticles: Boosting visible-light-driven photocatalytic activity

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ABSTRACT

In this study, we have developed a novel approach for depositing carbon dots (CDs) and BiOI nanoparticles onto the surface of graphitic carbon nitride (g-C_3N_4) nanosheets (gCN-NS). The synthesized materials were subsequently characterized by means of XRD, EDX, SEM, HRTEM, UV–vis DRS, FT-IR, TGA, XPS, PL, and BET instruments. The photocatalytic performance of the synthesized nanocomposites was evaluated by degradations of Rhodamine B (RhB), methylene blue (MB), methyl orange (MO), and Fuchsine under visible-light illumination. The obtained results revealed that the ternary gCN-NS/CDs/BiOI nanocomposites exhibited much better photocatalytic performance compared to the bare and binary photocatalysts due to the enhanced visible light absorption and improved charge separation. The gCN-NS/CDs/BiOI (30%) nanocomposite displayed superior photocatalytic performance for the removal of RhB, MB, MO, and fuchsine, which is about 29.5, 17.7, 10.9, and 16.5 times higher than that of the gCN. A good recyclability was also observed for the ternary nanocomposite after five cycles. Based on the obtained results, possible mechanism for the substantial enhancement of the photocatalytic performance via depositing the CDs and BiOI nanoparticles onto the surface of gCN-NS was discussed.

1. Introduction

In recent years, serious environmental issues related to water contamination with various synthetic chemicals are alarming due to rapid industrialization and an increase in human activity [1–3]. Hence, providing fresh water is vital for all ecosystems. On the other hand, the reduction of carbon dioxide to fuels and the production of hydrogen fuel are promising strategies for providing renewable and green energy [4,5]. Therefore, many substantial efforts have been made to provide low-cost and efficient strategies to address environmental and energy crises [6–8]. Semiconductor-based photocatalysis is known as a promising technology to solve these issues in the future [9–12]. Heterogeneous photocatalytic processes can utilize solar energy to find solution to these crises [13–18]. Since the pioneering work of Wang and coworkers [19], graphitic carbon nitride (g-C_3N_4, abbreviated as gCN) with a two-dimensional polymeric structure has attracted much attention for various applications [19]. Owing to its fascinating characteristics, including easy synthesis, low-cost starting compounds, and considerable physicochemical stability, gCN has shown high potential to be one of the most feasible next generation photocatalysts [20,21]. It has been demonstrated that gCN with the band gap of 2.7 eV can be used as a visible-light-active photocatalyst, particularly after some modifications to decrease the recombination rate of the photoinduced electron–hole (e^-/h^+) pairs and enhance the visible-light absorption [22,23]. The generally applied modification strategies include morphology control, anionic and cationic doping, integrating with other semiconductor having matched energy levels, and nanostructure construction [24–35].

Here, we have applied a combined strategy of morphology control, nonmetallic doping, and integration with a narrow-bandgap semiconductor to improve the photocatalytic performance of gCN. In this context, the gCN nanosheets (gCN-NS) were first fabricated by a thermal method [36]. For enhancing the visible-light absorption and fast transfer of the photoinduced e^-/h^+ pairs, carbon dots (CDs) were deposited over the gCN-NS. Finally, BiOI nanoparticles were combined with the formed gCN-NS/CDs nanocomposites to fabricate ternary gCN-NS/CDs/BiOI nanocomposites. Thanks to its narrow band gap (1.77–1.92 eV) [37], BiOI was introduced into the gCN-NS/CDs system to enhance the visible-light harvesting ability of gCN-NS, leading to the enhanced photocatalytic performance. The prepared ternary nanocomposites were systematically characterized and their photocatalytic performance was evaluated toward

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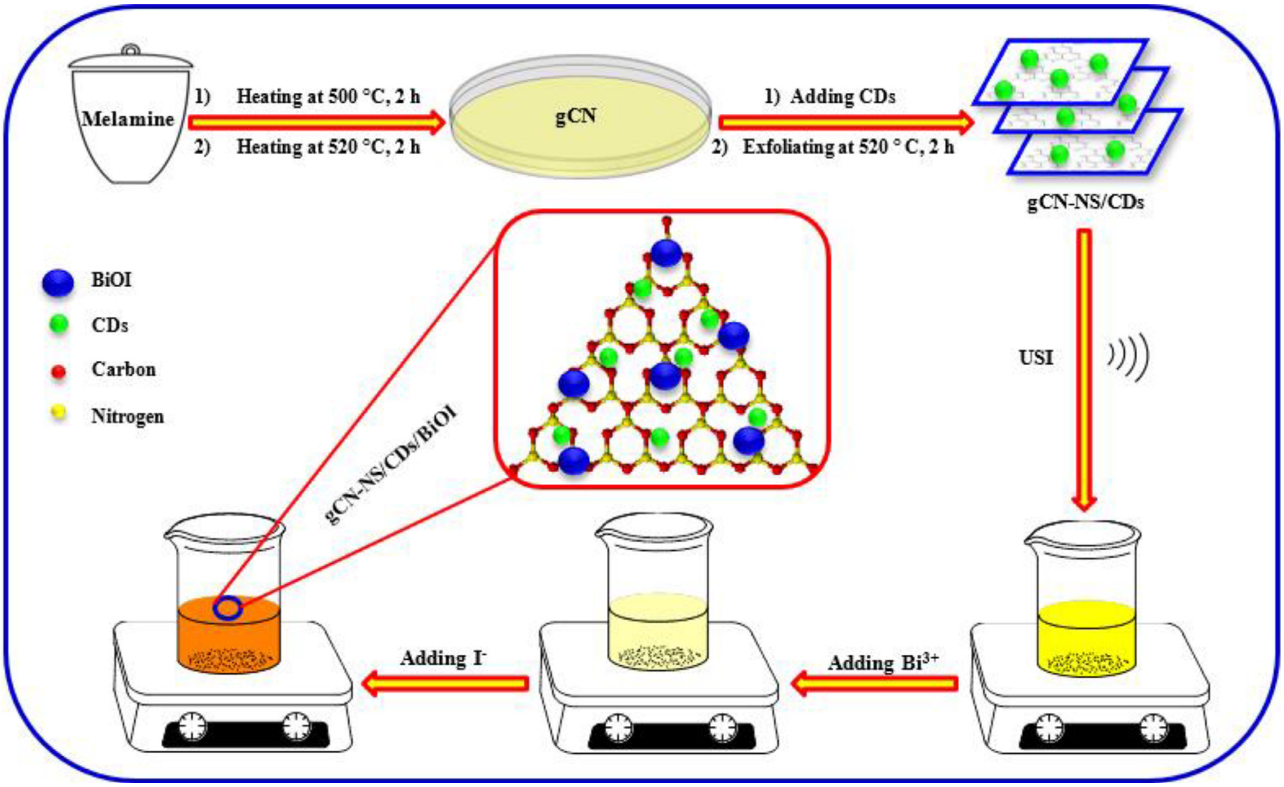

Scheme 1. Schematic illustration for preparation of the gCN-NS/CDs/BiOI nanocomposites.

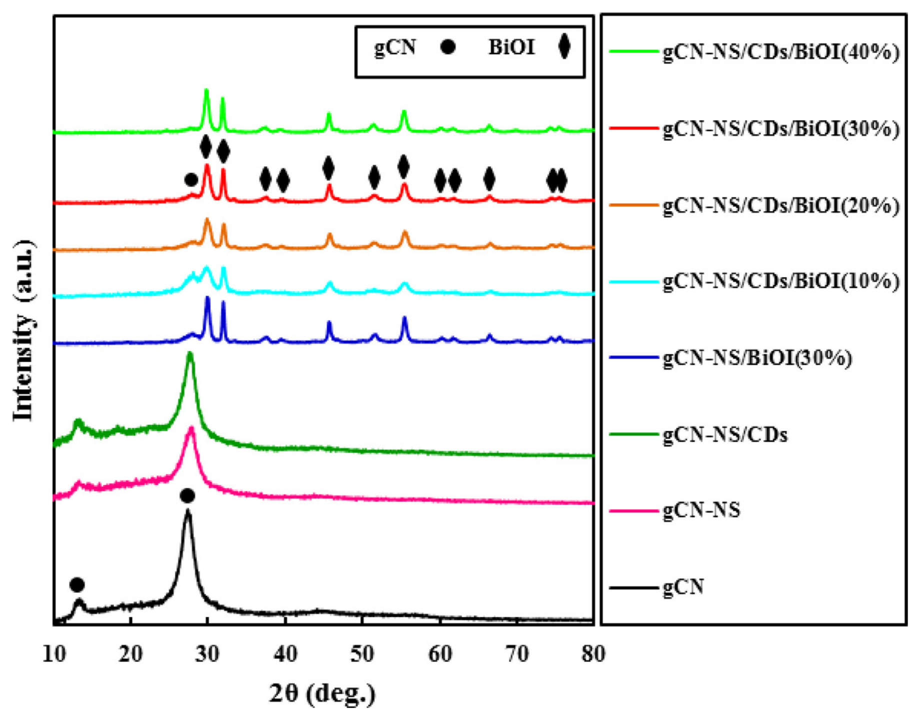

Fig. 1. XRD patterns of gCN, gCN-NS, gCN-NS/CDs, gCN-NS/BiOI (30%), and gCNNS/CDs/BiOI nanocomposites with different contents of BiOI.

the photodegradation of organic pollutants under visible light. The results demonstrated that the BiOI content, calcination temperature, and scavengers of reactive species play an important role in the photodegradation of organic pollutants under visible-light irradiation. Possible mechanism for the substantial enhancement of the photocatalytic performance is also discussed.

2. Experimental

2.1. Preparation

Synthesis of gCN and gCN-NS: The gCN powder was synthesized by heating melamine (Loba Chemie, 99.2%) according to the

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