Photocatalytic Activity of g-C_3N_4 Immobilized on Floating Polyurethane Foam

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Abstract

We evaluated the photocatalytic activity of floating g-C_3N_4 to degrade Methyl Orange as a model of dye pollutants. g-C_3N_4 was synthesized by the calcination of melamine and then immobilized onto PU foam through incipient wetness impregnation. Characterization techniques included XRD, DRS, and FESEM-EDS analyses. g-C_3N_4@PU photocatalyst could completely eliminate Methyl Orange dye during 300 min irradiation by simulated sunlight. The reusability experiments also indicated that g-C_3N_4 could be active after five cycles. The scavenging of free radical species revealed that all three active species (i.e., photogenerated holes, hydroxy radicals, and superoxide anions) had significant contributions to the photocatalytic degradation of Methyl Orange.

Keywords

Floating Photocatalyst, g-C_3N_4, Polyurethane Foam, Methyl Orange Dye.

Introduction

Currently, around one billion people worldwide suffer from poor quality of drinking water. Diverse methods such as adsorption, chlorination, ozonation, coagulation, sedimentation, chemical precipitation, and membrane filtration can be employed to eliminate contaminants in water. However, most of these methods merely transfer pollutants into other phases or transform them into other products. In addition, these techniques are often expensive and create secondary pollutants.

Advanced oxidation methods, especially photocatalysis, is a promising approach to address these drawbacks. The exposure of a semiconductor, used as a photocatalyst, to a light irradiation source causes the formation of hydroxyl radicals and superoxide anions on the photocatalyst's surface. These reactive species can then react with organic pollutants present in the water in which the photocatalyst is submerged, resulting in the degradation of contaminants. The treatment conditions can be optimized to minimize the formation of harmful transformation products (Falletta et al. 2022).

Graphitic carbon nitride (g-C_3N_4) is a promising photocatalyst for water treatment due to its narrow band gap energy, high thermal and chemical stability, and superhydrophilicity. Nonetheless, the rapid recombination of photo-induced charge carriers and the difficult separation of g-C_3N_4 powder from the water after treatment have restricted its practical application (Li et al. 2022).

To overcome these limitations, we aimed to design and construct a g-C_3N_4 immobilized on Polyurethane (PU) foam floating photocatalyst for the degradation of aqueous contaminants.

The use of PU foam as a support not only facilitates the separation of the photocatalyst from the water, but also can prevent the rapid recombination of electron-hole pairs considering that the PU foam also provides an electron sink. The increased surface area, enhanced adsorption capability of pollutants, and high light photons absorbance are other advantages of PU foam relative to other potential supports for the photocatalyst.

Methodology

We synthesized the g-C_3N_4 photocatalyst by the calcination of melamine and then immobilized the as-prepared photocatalyst on the surface of PU foam through incipient wetness impregnation.

We investigated the photocatalytic activity of g-C_3N_4 immobilized on PU foam using Methyl Orange (MO) as a model compound. The floating g-C_3N_4 with an active surface area of 192 cm^2/L (containing around 0.1 g photocatalyst) was placed in a 10 ppm MO solution and then kept in the dark for 60 min to reach absorption-desorption equilibrium. The solution containing the photocatalyst was then exposed to a simulated sunlight irradiation (Ultra-Vitalux OSRAM, 300 W, Germany) with an intensity of 35 W/m2, which was mounted above the reactor. To assess the contribution of active species, we also conducted the photocatalyst experiments in presence of 1 mM methanol, isopropanol, and benzoquinone as a photogenerated hole, hydroxyl radical, and anion superoxide scavenger, respectively. We repeated all photocatalytic experiments three times. The presented results in this article are the average of these repetitions.

Results and discussion

Fig. 1(a) indicates the differential reflectance spectroscopy (DRS) of g-C_3N_4 immobilized on PU foam. The internal figure is the Tauc plot of the as-prepared photocatalyst to measure the band gap energy. Based on Fig. 1(a), a redshift towards 480 nm (equal to 2.7 eV) was observed for g-C_3N_4 immobilized on PU foam, indicating its photocatalytic activity under visible light irradiation.

According to the XRD pattern of g-C_3N_4 (Fig. 1(b)), two dominant diffraction peaks were observed at 13.2° and 27.5°, corresponding to the miler indexes of (100) and (002), respectively. These peaks are attributed to an intralayer structural packing motif and an aromatic interlayer stacking peak, respectively (Li et al. 2022).

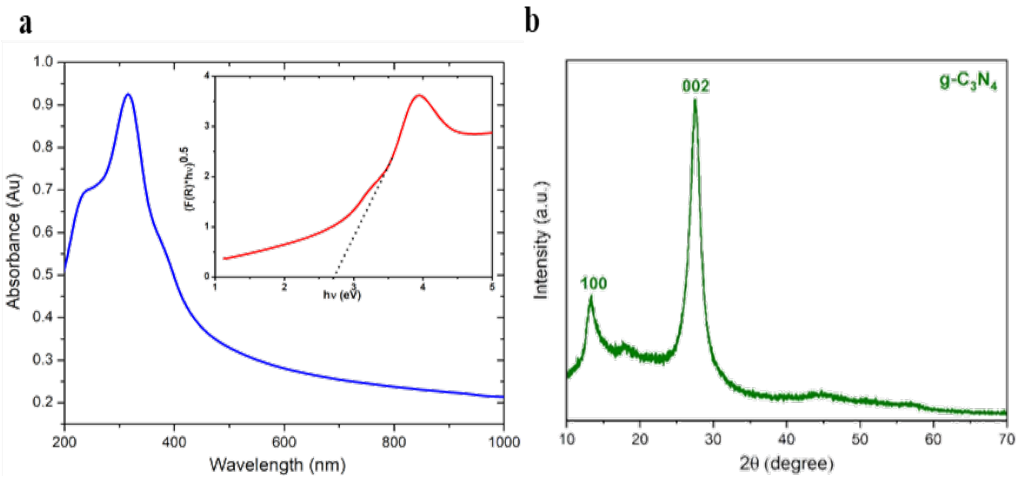

Fig. 1. (a) DRS analysis of g-C_3N_4@PU photocatalyst and (b) XRD pattern of g-C_3N_4@PU photocatalyst.

The morphology and elemental composition of the photocatalyst were characterized by FESEM-EDS analysis. g-C_3N_4 immobilized on PU foam had a microstructure with a rough surface, as shown in Fig. 2(a). Based on Figs. 2(b)-(d), carbon and nitrogen were the main elements and were dispersed uniformly on the surface of PU foam.

Fig. 3(a) demonstrates the photocatalytic activity of g-C_3N_4@PU for the degradation of MO and the free radical scavenging experiments. 100% of MO was degraded during 300 min of simulated sunlight irradiation. In the presence of isopropanol, methanol, and benzoquinone, the photocatalytic degradation was decreased from 100% to 25%, 40%, and 45%, respectively. This result reveals that all active species (i.e., photogenerated holes, hydroxy radicals, and superoxide anions) had significant contributions to the degradation of MO by g-C_3N_4@PU. Fig. 3(b) summarizes the reusability of g-C_3N_4@PU. After five sequence recycling steps, the photocatalytic degradation declined from 100% to around 80%. This reduction can be attributed to the poisoning of the photocatalyst surface by generated by-products.

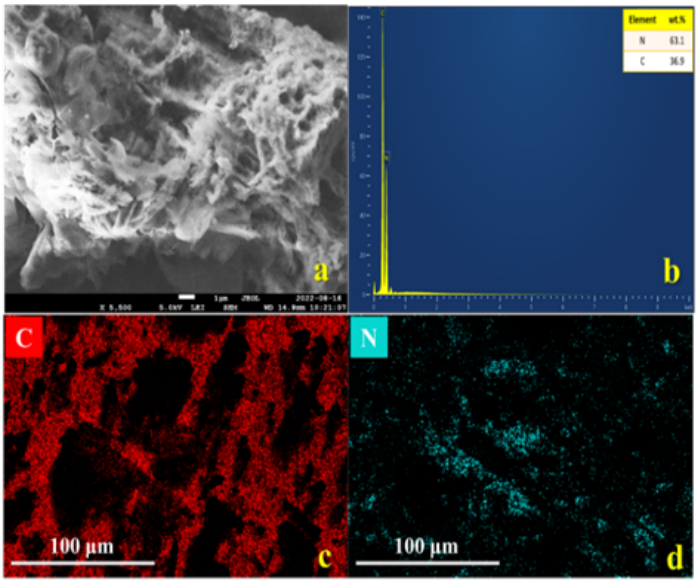

Fig. 2. (a) FESEM image, (b) EDS spectrum, and (c, d) EDS mappings of g-C_3N_4@PU photocatalyst.

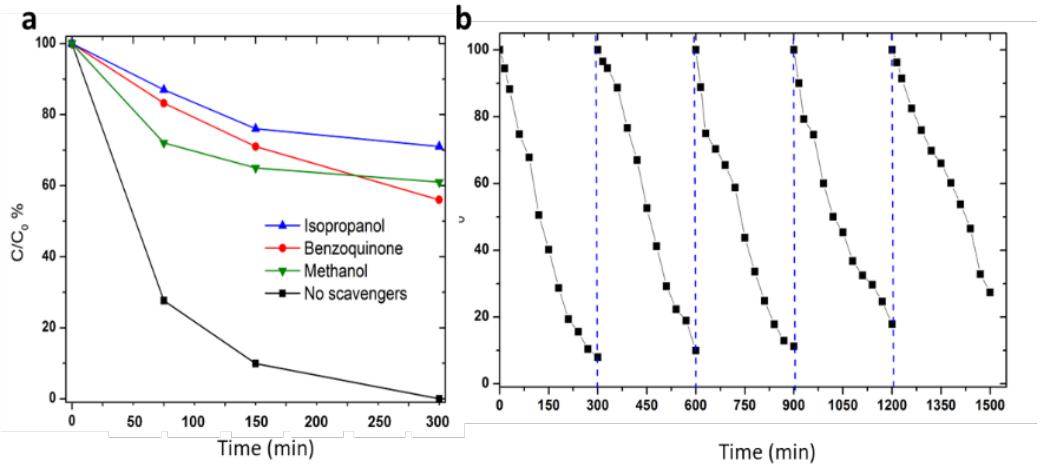

Fig. 3. (a) Photocatalytic activity of g-C_3N_4@PU and free radical scavenging experiments (b) Reusability of g-C_3N_4@PU for five cycles.

Conclusion

We fabricated a floating g-C_3N_4 immobilized on PU foam which was shown to degrade completely MO dye when exposed over 300 min to simulated sunlight irradiation and to maintain its photocatalytic activity over a few cycles. The results are encouraging and suggest that g-C_3N_4 and the immobilization on PU foam provide a promising approach to degrade contaminants in water.

Acknowledgments

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