Photocatalytic performance of carbon nitride nanosheets synthesized by a bottom-up approach

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ABSTRACT

Graphitic carbon nitride has gotten more attention in the photocatalysis field over the past decade due to its electronic and structural properties. Photocatalytic activity of bulk g-C_3N_4 can be improved by producing g-C_3N_4 nanosheets. Herein, g-C_3N_4 nanosheets were synthesized through one-step polymerization using ammonium chloride (NH_4Cl) as a blowing agent. Both adsorption capacity and photodegradation efficiency of g-C_3N_4 nanosheets were improved and showed 42% efficiency rather than bulk g-C_3N_4 which showed only 6% degradation after 180 min visible light radiation.

INTRODUCTION

Synthetic dyes that are used by many industries such as textile, paint, printing, paper, etc. contaminate water resources. Over the past few decades, photocatalysis has gotten more attention because of using sunlight as an energy resource, mild conditions and low cost [1]. Graphitic carbon nitride (g-C_3N_4) is a polymeric semiconductor with 2.7 eV band gap, suitable conduction and valence band position and layered structure [2]. Bulk g-C_3N_4 has poor photocatalytic activity due to the low specific area and high recombination rate of the photogenerated carriers [3]. So, strategies that can boost the activity of the bulk, have been in considerable attention. . Using a chemical blowing agent is a bottom-up approach, time-effective, and one-step process. During polymerization, the released gas acts as a gas template to overcome Van der Waals forces [4]. Ammonium salts like ammonium fluoride (NH_4F), chloride (NH_4Cl) and (NH_4Br) bromide are the most common salts used in the process.

OBJECTIVE

In the present study, g-C_3N_4 in bulk and nanosheet forms was synthesized. The structural, morphological and optical properties were characterized to address the photocatalytic application of g-C_3N_4.

MATERIALS & METHODS

Bulk g-C_3N_4 photocatalyst sample was synthesized by thermal polymerization of melamine as a precursor. Melamine was polymerized in an alumina crucible with a lid. By heating melamine at 550 °C with a heating rate of 10 °C/min for 4 h in a muffle furnace and after naturally cooling down to room temperature the resultant yellow product was bulk g-C_3N_4 and ground for further use. Then, g-C_3N_4 nanosheets were prepared through the bottom-up approach. After dry mixing of melamine and ammonium chloride thoroughly with a molar ratio of 1:10, the uniform mixture was put in the alumina crucible with a lid. The same heating program for bulk g-C_3N_4 was operated to prepare g-C_3N_4 nanosheets. The light yellow product was g-C_3N_4 nanosheets and ground for further use.

RESULTS

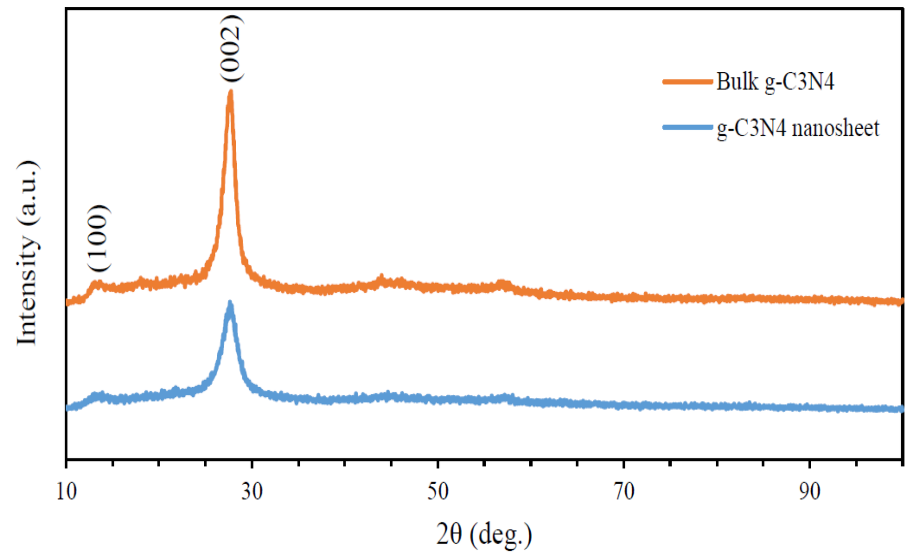

Figure 1: XRD patterns of the photocatalysts.

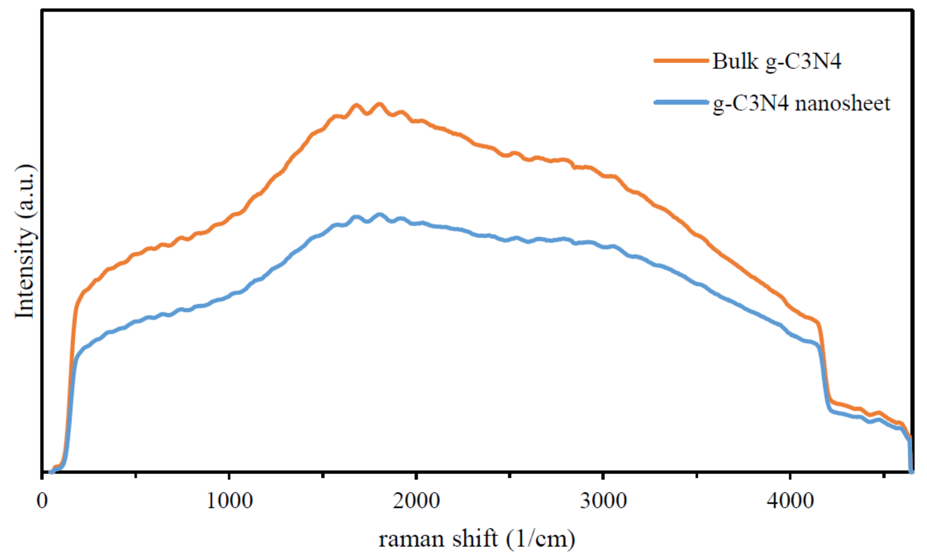

Figure 2: Raman spectra of the photocatalysts.

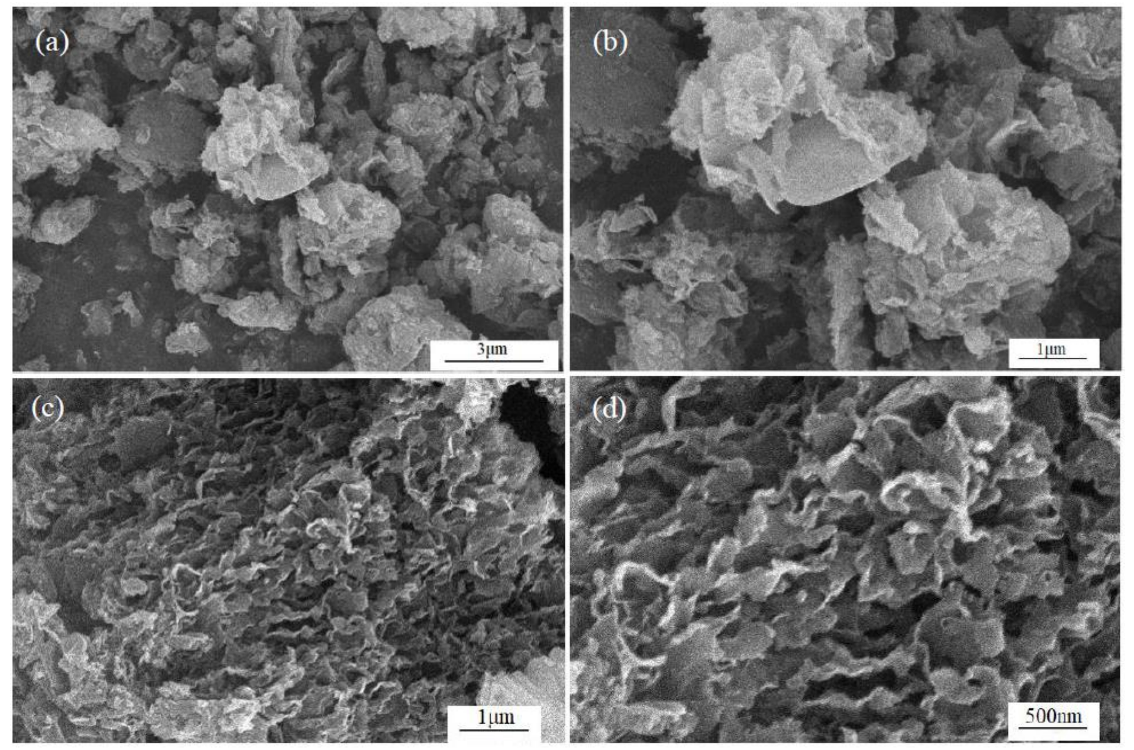

Figure 3: FESEM images of (a and b) bulk g-C3N4, (c and d) g-C3N4 nanosheets at different magnifications.

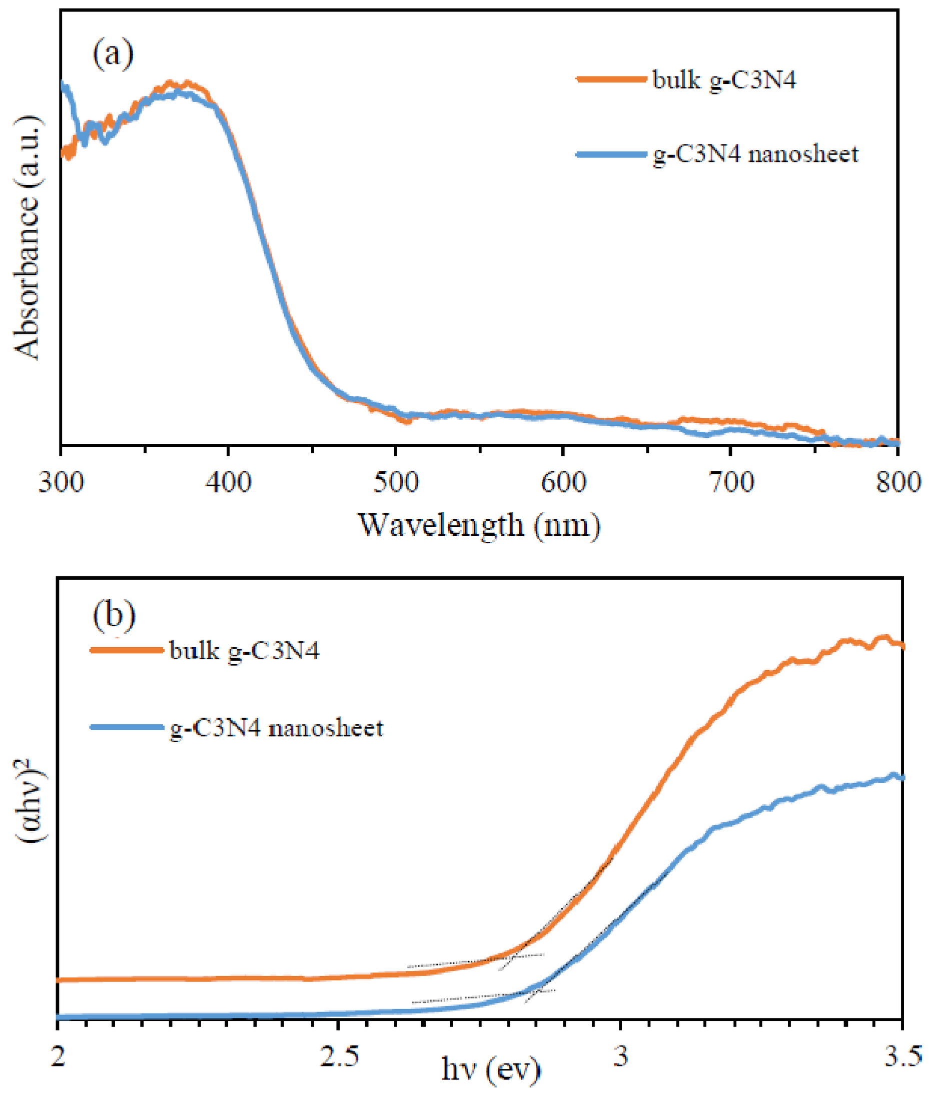

Figure 4: (a) UV-vis diffuse reflectance spectra and (b) the Tauc plots of the photocatalysts.

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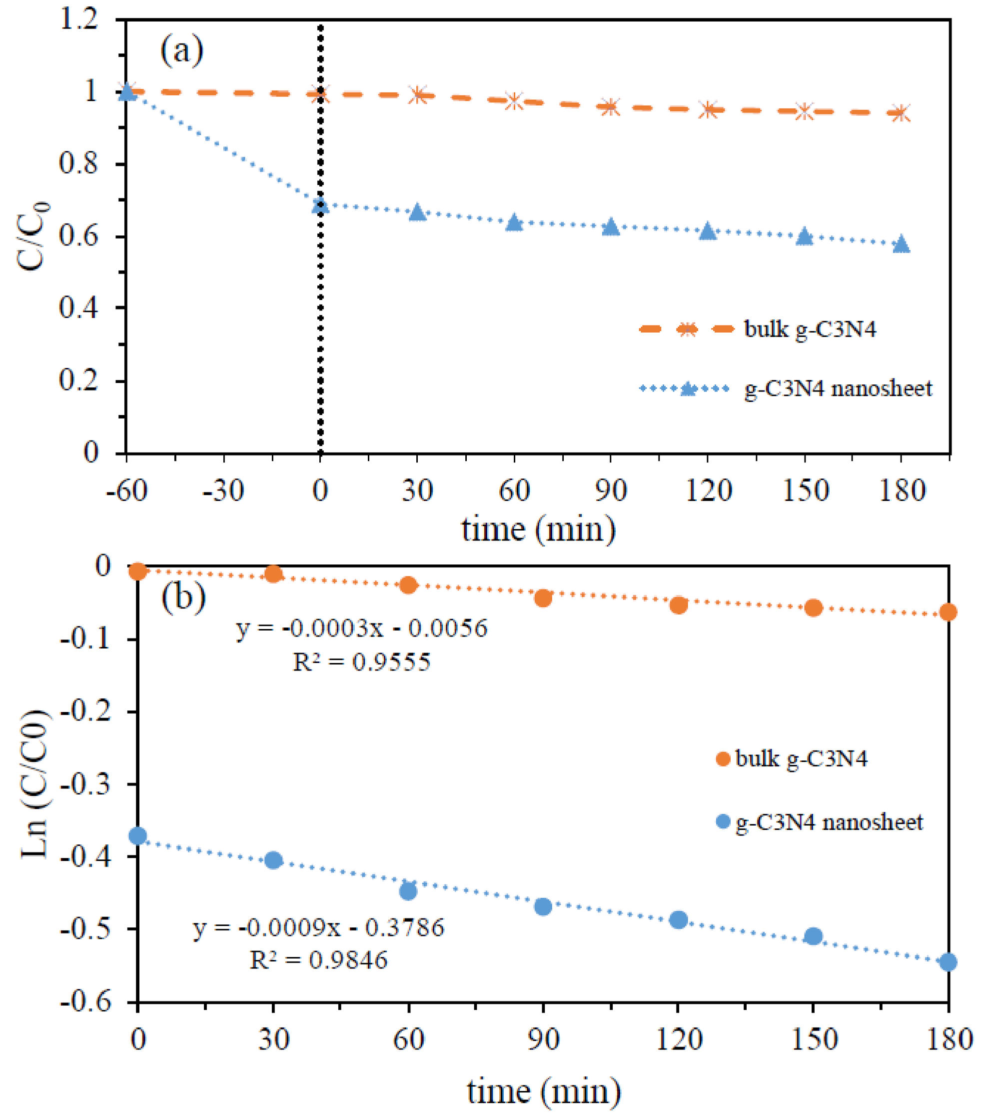

Figure 5: Photocatalytic performance of the samples under visible light irradiation using 2 mg/L MB solution.

CONCLUSIONS

- XRD patterns showed that NH_4Cl introduction caused peak broadening and reduction in intensity.
- The reduction in intensity in Raman spectra further confirmed that nanosheets were successfully synthesized.
- FESEM images exhibited that bulk g-C_3N_4 had irregular morphology with an approximate size of 3 μm. Whereas, g-C_3N_4 nanosheets showed 2D structure with a thickness of 5 nm.
- The DRS results showed a slight blue shift in absorption edge and the calculated band gaps for bulk and nanosheets were 2.80 and 2.85 eV, respectively.
- The adsorption capacity of bulk g-C_3N_4 was 0.3 mg/g. But, for g-C_3N_4 nanosheets, a 31-fold increase was observed.
- Photo-degradation efficiency of 2 mg/L MB solution for bulk g-C_3N_4 and g-C_3N_4 nanosheets were 6% and 42%, respectively.
- The photo-degradation process followed a pseudo-first-order model and the calculated rate constants for bulk g-C_3N_4 and g-C_3N_4 nanosheets were 0.0003 and 0.0009 min^{-1}, respectively.

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