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Short communication

GCN decorated manganese oxide for photocatalytic degradation of methylene blue

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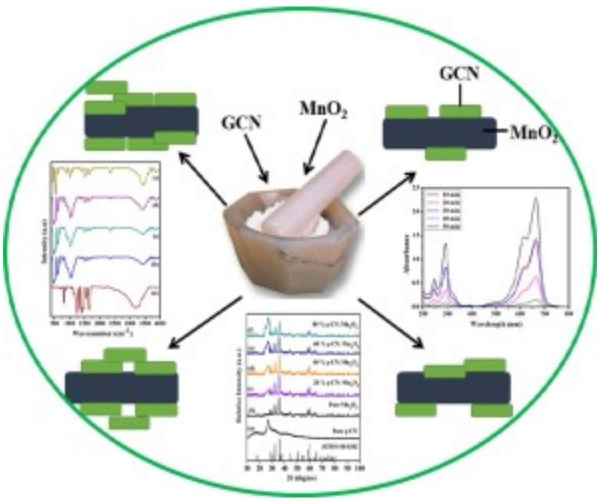
Highlights

- The cubic structured GCN adorned Mn_2O_3 was prepared by the co-precipitation method.
- The surface micrographs were captured by SEM technique.
- The functional group analysis of GCN decorated Mn2O3 was studied by FT-IR analysis.
- The optimized GCN decorated Mn2O3 exposes excellent photocatalytic manners.

Abstract

We have synthesized different concentrations of graphitic carbon nitride (GCN) (20 %, 40 %, 60 %, and 80 %) decorated manganese oxide (Mn_2O_3) for photocatalytic degradation of the organic contaminant methylene blue (MB) in the current study. Powder X-ray diffraction (PXRD) research was used to investigate the crystalline nature of synthesized GCN-coated Mn_2O_3. Scanning electron microscopy (SEM) analysis was used to investigate the surface morphology of produced materials. The element purity of GCN-adorned Mn_2O_3 materials was studied by energy dispersive spectroscopy (EDS) to identify the composition of elements. Fourier transformation infrared (FTIR) spectroscopy was used to investigate the functional group analysis of synthesised GCN adorned Mn_2O_3. GCN adorned Mn_2O_3 materials with different concentrations of GCN (20 %, 40 %, 60 %, and 80 %) were used as photocatalysts for the degradation of MB dye. Under visible light illumination, 60 % of GCN decorated Mn_2O_3 demonstrated excellent photocatalytic performance for MB breakdown, with a capability of above 99%. When compared to other Mn_2O_3 materials, the improved photocatalytic activity was attributed to the good crystallinity, defined shape, superior optical band gap, and smaller particle size.

Graphical abstract



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Introduction

Among the registered semiconductors, manganese oxide (Mn_2O_3) is widely used as a photocatalyst [1], lithium battery [2], and supercapacitor [3] due to its non-toxicity, low cost, and excellent photovoltaic properties [4]. In the case of photocatalysts,

Mn_2O_3 can theoretically respond to light in the infrared due to its narrow bandgap (about 1.9 eV) [5]. However, the initial photoactivity of Mn_2O_3 was insufficient due to insufficient CB and VB potentials and a low quantum yield [6]. To solve this problem, Mn_2O_3 was combined with other materials to form a heterostructure composite material to improve photocatalytic performance.

Recently, Mn_2O_3 has attracted much attention in the removal of impurities from organic dyes due to its unique structure and physicochemical properties found in polymorphs such as α, β, γ, λ, and δ [7]. It is reported that the removal efficiency of Mn_2O_3 dye impurities depends not only on their crystallographic shape, but also on morphology, particle size, crystallinity, and bulk density [8]. Recently J. Tan et al [9] reported that δ- Mn_2O_3 exhibits a strong oxidative capacity toward phenolic compounds and aniline compounds. β- Mn_2O_3 has been reported to have an excellent ability to degrade methylene blue in the presence of H_2O_2. Liang et al [10] It was found that the activity of the catalyst in the oxidation of carbon monoxide (CO) follows the series $\alpha \approx \delta > \gamma > \beta$-$MnO_2$. Nguyen et al reported the decolourization efficiency of RhB for α-, β- and δ-MnO_2 increases with decreasing solution pH. It was shown that α- Mn_2O_3 has the highest activity against the degradation of RhB at pH 2–6. Mn_2O_3, which has hitherto been used as a photocatalyst for the decomposition of organic pollutants, has been in the form of a powder obtained by various chemical processes [11].

Raji Atchudan et al [12] synthesized the novel nitrogen-doped carbon dots adorned zinc oxide composite fabricated by an economical wet-impregnation method for photodegradation of MB. They highly recommended the N-CDs@ZnO composite can be considered an ideal photocatalyst in the field of dye degradation. Similar to that, Raji Atchudan et al [13] prepared titanium dioxide nanoparticles@nitrogen-doped carbon (TiO_2 NPs@C) nanocomposite synthesized by hydrothermal method. They reported TiO_2 NPs@C nanocomposite showed excellent photocatalytic performance on MB under irradiation of UV-light and the degradation efficiency (>90 %). Likewise, the photocatalytic degradation efficiency of the ZnO@N-C hybrid composite on MB was reported by Raji Atchudan et al [14]. They suggested the synthesized ZnO@N-C hybrid composite is an ideal candidate for the photocatalytic degradation of MB and exhibit a maximum degradation efficiency of 95 % in a neutral medium under UV-light irradiation for 60 min. Periyasamy thirukumaran et al [15] prepared the novel nitrogen-doped carbon balls adorned with ZnO nanoparticles (ZnO@CBs) through a simple carbonization method. They optimized the ZnO@CBs and strongly suggested the optimized ZnO@CBs is a promising candidate for the photocatalytic degradation of MB.

The Mn_2O_3 is widely used in the synthesis of photocatalysts modified with complex ions for their excellent photocatalytic performancee [16], [17]. Thin-film Fe_3O_4 nanocomposites coated with Mn_2O_3 nanosheets synthesized by hydrothermal method combined with soft sonication showed excellent photocatalytic efficiency in the decomposition of methylene blue [18]. In addition, it was possible to effectively separate the Mn_2O_3/Fe_3O_4 nanocomposites due to their ferromagnetic properties [18].

In recent years, graphite nitride (GCN) has attracted a lot of attention for photocatalytic applications [19]. It is considered a promising photocatalytic material due to its clear structure, high electronegativity, stability, and catalytic activity [20]. However, GCN has a low band energy value, and due to the rapid charge separation recombination, it will be used in practical applications [21]. Efficient designs of GCN-based photocatalysts, such as soft modelling, delamination, elemental doping, and formation of heterojunctions, attract attention [22]. Among many photocatalysts, graphite carbon nitride (g-C_3N_4) is the most important representative of inorganic and organic semiconductor photocatalysts [23]. As is known, g-C_3N_4 is usually a two-dimensional layered polymeric semiconductor with a strongly non-localized p-conjugated electron system [24]. To date, various chemical methods for the synthesis of g-C_3N_4 have been developed, such as thermal polymerization, sorbothermal chemical vapor deposition, and electrochemical vapor deposition. Although g-C_3N_4 has excellent photocatalytic activity, several drawbacks remain, such as low visible light absorption, recombination of photogenerated charge carriers, and relatively small specific surface area.

It is well-known that the GCN is a metal-free, visible-light responsive and appropriate bang-gap photocatalyst that has unique superiorities like ease of synthesis, economy, stability, and non-toxicity. Unfortunately, GCN possesses lower electrical conductivity and lesser active surface area which limits its application in electrocatalysis. As a solution to overcome these shortcomings, several strategies like doping, synthesis of mesoporous structures, coupling with carbon allotropes, conducting polymers, and transition metal-oxides have gained considerable interest nowadays. Which, the work involves the blending of transition metal oxide, Mn_2O_3 with GCN. Mn_2O_3 is electronic compatible with GCN to output enhanced photocatalytic activity. The earth-abundancy, low-cost, thermal and chemical stability, non-toxicity, and high catalytic activity enable Mn_2O_3 to retain its position in photocatalytic applications. Therefore, GCN decorated Mn_2O_3 for photocatalytic degradation of organic dye-based research is needed. Within this mind, this work focus on the GCN decorated Mn_2O_3.

Section snippets

Sample preparation

Urea was selected as a precursor for the preparation of graphitic carbon nitride. Urea was thermally treated up to 550°C after cooling to room temperature the pale-yellow colour sample was referred to as a pristine carbon nitride. Mn_2O_3 was mixed together with the as-prepared GCN by the use of a mortar and pestle the resulting mixture was allowed to treat thermally at 450°C for making a composite.

Methylene blue (Merck) and manganese dioxide (Merck) were used. MB solution was prepared with…

PXRD analysis

Fig. 1 (a) showed the observed powder X-ray diffraction profile of prepared materials. The phase pure cubic structured Mn_2O_3 materials were identified by PXRD analysis. There were no additional peaks are observed in the observed PXRD patterns which confirms the clear crystal system of Mn_2O_3 as shown in Fig. 1 (a). All the X-ray diffraction peaks perfectly match with the standard JCPDS patterns (card no: 80-0382) [25]. The well-matched diffraction patterns of prepared Mn_2O_3 confirm the phase…

Conclusion

In conclusion, the different concentrations of GCN (20 %, 40 %, 60 %, and 80 %) decorated manganese oxide (Mn_2O_3) prepared by a simple co-precipitation route and characterized by PXRD, SEM, and photocatalytic techniques. Characterization by PXRD confirmed that all Mn_2O_3 materials prepared were phase-pure cubic structures. Irregular pebble stone-shaped morphology was observed in the SEM measurement. The functional group analysis of synthesised GCN added Mn_2O_3 was studied by FTIR investigation.…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper....

Acknowledgment

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