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Enhanced photocatalytic performance of pebble stone like $CuMoO_4$ photocatalyst for the degradation of organic pollutant

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Abstract

Hydrothermal synthesis of $CuMoO_4$ photocatalyst for the photocatalytic degradation of methylene blue (MB) in the aqueous phase was performed under visible light illumination. The produced nanoparticle was characterized using X-ray Powder Diffraction (XRD), Fourier-transform infrared spectroscopy (FT-IR), Scanning Electron Microscopy (SEM), Ultraviolet–visible diffuse reflectance spectra (DRS-UV), Energy-dispersive X-ray (EDAX) spectroscopy and X-ray photoelectron spectroscopy (XPS) to investigate the nanoparticles' structures, functional groups, morphologies, bandgap energy, qualitative and oxidation state of elemental analysis. The methylene blue (MB) photodegradation process using 30mg of the photocatalyst at 1µM concentration resulted in a greater degradation efficiency under visible light. A maximal photocatalytic performance of 94.70% was attained for 50min. The effects of variables on the photocatalytic process, such as adsorbent dosage, catalyst and scavenger concentrations, recycling effectiveness, and MB concentration, have been thoroughly studied.

Introduction

Water covers more than two-thirds of the Earth's surface, owing to the reservoirs of oceans, lakes, large rivers, and other inland aqua sources. However, human activities has polluted all water supplies. Today, water contamination is a serious, complicated issue that affects both people and other living things. It is demonstrated to be a global problem brought on by numerous industrial and pharmaceutical wastes [[1], [2], [3], [4]]. Water is regularly polluted by heavy metals, deadly chemical compounds, and textile dyes from numerous enterprises [5]. The photocatalytic system now provides a benign mechanism to the environment and is frequently used to degrade the organic pollutant portion of industrial wastes [6].

Numerous studies have recently been used to improve the photocatalytic method for removing contaminants from wastewater and these techniques, in particular, have a solid potential to mineralize the organic contaminants [[7], [8], [9], [10], [11], [12], [13], [14], [15]]. Photocatalytic pollutant degradation is a difficult task in environmental sciences. The practical and environmentally friendly "Advanced oxidation process" (AOP) is one of the photocatalytic techniques used to clean wastewater [16]. Numerous inorganic semiconductor metal oxides are employed in the photocatalytic process, such as TiO_2, ZnO, ZnS, SnO_2, CuO, etc. [[17], [18], [19], [20], [21], [22]]. ZnO is a very effective material for degradation compared to semiconducting materials like TiO_2 because of their vast band gap and good photosensitivity [23]. Due to its intriguing size and shape-dependent optical, magnetic, and electrical properties, metal molybdate ($MMoO_4$) has received much attention [[24], [25], [26], [27], [28], [29]]. Molybdate of the transition metal is used in various products, including gas sensors, optical fibres, humidity sensors, pigments, catalytic activity, biological processes, etc.

One of the crucial inorganic substances is copper molybdate ($CuMoO_4$), which has a wide range of applications, including microwave and optical fibres, humidity sensors, photo anodes, laser hosts, and catalysts. Additionally, it is thought to be a possible contender as a visible light photocatalyst for the oxidation of organic pollutants. Numerous investigations on the characterization and preparation of copper molybdate have recently been published [[30], [31], [32]]. Molybdenum-based oxide materials have been used widely in lithium-ion batteries and photocatalysis in recent years [33,34]. "$PbMoO_4$ and $CdMoO_4$, for instance, demonstrated strong photodegradation performance for Rh B" [35,36]. In lithium-ion batteries, $CoMoO_4$ and $Mn_2Mo_3O_8$ had larger reversible capacities and superior cycle stability [37,38]. In specific ways, the photocatalytic degradation of dyes, photocurrent response, and lithium-ion batteries received more attention than other structural materials [39,40]. We sought to determine whether highly mono-dispersed $CuMoO_4$ particles had significant potential for application in various electroluminescent devices, including photocatalysis, photocurrent, and energy conversion, based on the studies mentioned above. In the past decades, lots of $CuMoO_4$ nanomaterials were reported. Mainly, it is focused on the catalytic degradation of organic pollutants, gas sensing and supercapacitors applications. Most of the previous literature reports the degradation of some organic dyes such as Rh B, Thymol blue, Yellow 5 and 4-chloro phenol, etc. However, in this study, we report a dye called methylene blue (MB) that is more efficient at degrading under visible light than other dyes. Also, the irradiation time for the degradation is deficient compared to others. The comparative accounts of the photocatalytic activity of $CuMoO_4$ with various previous reports for the degradation of organic pollutants were detailed.

In this work, we investigated $CuMoO_4$'s performance and characterized a few of its features. Regarding photocatalytic applications, prior research has demonstrated that semiconductor compounds may degrade the most persistent organic pollutants, including colouring agents, detergents, and volatile organic compounds, when exposed to ultraviolet light [41,42]. Due to its widespread use and challenging biodegradation, MB was chosen as a model contaminant in this study to assess the degrading activity of $CuMoO_4$ under visible light irradiation. Additionally, a detailed investigation of CuMoO4 photocatalytic properties was conducted.

Section snippets

Materials and reagents

Ammonium molybdate and copper nitrate is the primary raw material purchased from Sigma Aldrich, India. And the other ingredients, including sodium hydroxide, urea and methylene blue (Merck Chemicals, India), are the other raw materials. All the solutions are prepared with de-ionized water.…

Synthesize of $CuMoO_4$ (CM)

A straightforward precipitation method was used to synthesize CuMoO4 (CM). The typical synthetic procedure is as follows: 0.726 g/L (3 mmol) of $(NH_4)_2MoO_4{\cdot}2H_2O$ was dissolved into 50 mL deionized water, and the …

Structure and morphology characteristics

The crystalline phase and the crystalline nature of the synthesized $CuMoO_4$ were analyzed using XRD shown in Fig. 1. The $CuMoO_4$ diffraction peaks match the $CuMoO_4$ standard card quite well (JCPDS card No. 36–0405). The diffraction pattern values of as-synthesized materials are easily predicted using the average atlas card values [43,44]. The characteristic 2θ regions of 15.29, 19.18, 24.15, 26.57, 29.54, 32.28, 33.58, 34.65, 35.96, 41.21, 44.55, 47.90 and 52.87° correspond to the reflections of…

Conclusion

In conclusion, $CuMoO_4$ was effectively synthesized by the hydrothermal process at a temperature of 160 °C, which offers a method that is efficient, simple, and easy to use for the synthesis of $CuMoO_4$ nanoparticles. Analyses using FT-IR, UV-DRS, XRD, SEM and XPS were performed on the nanoparticles of copper molybdate that had been synthesized. A UV visible diffuse reflectance spectrometer was utilized to obtain the value of 1.91 eV for the bandgap of $CuMoO_4$. SEM can show the morphological…

Author contributions

Lalitha Kamarasu: Conceptualization, Investigation, Writing - original draft, Data curation. **Ezhaveni Sathiyamoorthi:** Investigation, Data curation, Formal analysis, Writing - review & editing. **Satya Sree Nannapaneni**: Supervision, Writing - review & editing. **Saravanavadivu Arunachalam**: Methodology, Investigation, Supervision, Formal analysis. **Muthuraj Arunpandian**: Investigation, Supervision, Formal analysis. **Jintae Lee:** Data curation, Formal analysis Writing - review & editing. **PadmaPriya**…

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.…

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1 These authors contributed equally to this work.

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