Composite materials based on WO_3 nanoparticles and glass fibers towards pollutants removal

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Summary

Owing to their photocatalytic properties, semiconductor nanomaterials have been identified as a promising solution for addressing water scarcity and pollution issues, by assisting in removing organic contaminants.

In this work, the ability of WO_3 nanoparticles (NP) towards pollutants removal, by adsorption and photodegradation, was investigated. The high surface area and low bandgap energy, E_g, enabling the use under visible light, contribute to successful application for pollutants degradation.

Additionally, this work introduces a simple and straightforward method for modifying flexible transparent glass fibers (GF) with such nanocatalysts and its application for environmental remediation. The resulting composite materials, display effective coverage of NP and offer the advantage of easier catalyst recovery, compared to powder usage. The photocatalytic efficiency under natural sunlight suggests its potential for cost-effective applications.

Background

Water scarcity and pollution pose significant challenges to public health and the environment, requiring effective water purification technologies. Photoactive metal oxides catalysts have made notable progress towards contaminants removal from water, demonstrating the capability to break down pollutants, like dyes and pharmaceuticals, fast with minimal catalyst usage. However, although TiO_2 and ZnO are among the most studied catalysts, their high bandgap energy requires UV radiation for activation. Doping, self-sensitization, and combination of multiple semiconductors has allowed reducing E_g and electron/hole recombination rate. On the other hand, WO_3 can undergo activation by less energetic and more affordable light sources, as visible or sunlight [1].

The post-reaction separation of powder photocatalysts may be challenging, costly and result in secondary environmental pollution. Immobilizing photocatalysts on flexible and transparent substrates could solve these issues and offer advantages, as easy manipulation, large reaction areas, limited catalyst aggregation and improved light absorption due transparency to photoactivation.

Methodology

WO_3 NP were obtained by solvothermal method [2]; the same was used to prepare GF/WO_3 composite by adding GF. Adsorption studies were carried out using powder NP in 10 ppm dyes solution (rhodamine B – RhB, methylene blue – MB, methyl orange – MO and naphthol yellow S – NYS). WO_3 (or GF/WO_3) suspended in RhB solution, under a 450 W mercury lamp with a glass filter for UV blocking, were used for photocatalytic tests.

Results and Discussion

The successful synthesis of small size crystalline NP was confirmed by XRD and TEM analysis. High surface area, 183 m^2g^{-1}, was revealed by adsorption isotherm. From DRS analysis, a E_g of 2.26 eV evidences WO_3 absorption in the visible range. Synthesised NP showed high ability to RhB and MB cationic dyes adsorption (Table 1), whereas lower or no adsorption was observed for anionic dyes, MO and NYS, respectively. Apart to the environmental remediation relevance of such results, it allowed proofing the negatively charged nature of the NP surface.

Table 1. Adsorption capability of WO_3 NP.

Dye	Dye Adsorption (%)	m_{Dye} /m_{WO3} (mg/g)
NYS	0	0
MO	33	55
RhB	96	146
MB	97	146

The time profile depicted in Figure 1, towards RhB removal evidenced the synergistic contribution of adsorption (promoted by surface charge and high surface area) and photodegradation under visible light with ca. 75 % removal.

The mechanism of photodegradation was further investigated and a strong contribution of the holes to the photocatalytic performance suggests degradation may occur through an adsorption step preceding the direct oxidation on catalyst surface. Promising results were obtained for WO_3 NP immobilised on GF, achieving ca. 50 % removal within 1 h.

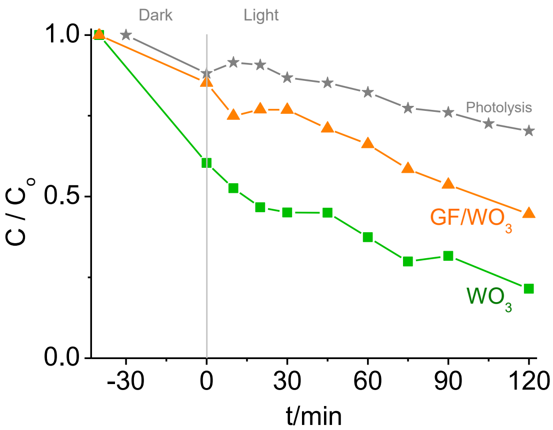

Figure 1. Time profile for photocatalytic degradation of RhB using WO_3 and GF/WO_3, under visible light.

Conclusions

Crystalline WO_3 NP with high surface area, and photoactive under visible light were obtained. They display high ability for cationic pollutants removal by combined effect of adsorption and photodegradation. Photocatalytic performance under visible light was imparted to glass substrates, sample GF/WO_3, with which a significant amount of pollutant can be removed.

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