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Green Synthesis of $TbFeO_3$ Nanostructures for UV Photocatalytic Dye Degradation

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Introduction

Water pollution from organic dyes, released by industries like textiles and printing, poses a severe threat to ecosystems and human health due to their toxic and non-biodegradable nature. Conventional wastewater treatment methods, such as adsorption or chemical coagulation, often fail to fully degrade these pollutants, leading to secondary contamination. Photocatalysis, which uses light-activated catalysts to break down organic compounds into harmless byproducts like carbon dioxide and water, offers a promising solution. A notable advancement in this field is the green synthesis of Terbium Ortho Ferrite ($TbFeO_3$) ceramic nanostructures using cherry and orange juice as eco-friendly reducing and stabilizing agents. These nanostructures demonstrate exceptional photocatalytic activity under UV light, providing a sustainable and cost-effective approach to dye degradation in wastewater. By integrating green chemistry principles with advanced nanomaterial design, $TbFeO_3$ nanostructures address the critical need for efficient and environmentally friendly remediation technologies [1].

Description

The green synthesis of $TbFeO_3$ nanostructures utilizes natural extracts from cherry and orange juice to produce highly crystalline, nanoscale particles. Unlike traditional synthesis methods that rely on toxic chemicals and energy-intensive processes, this approach employs the polyphenol and ascorbic acid content of fruit juices as natural reducing agents. The process involves mixing aqueous juice extracts with terbium and iron precursors to form a gel-like precursor, which is then calcined at high temperatures to yield orthorhombic $TbFeO_3$ nanostructures with a perovskite structure. These nanostructures, typically 20-50 nm in size, exhibit high surface area and uniform particle distribution. Characterization through techniques like X-ray diffraction, scanning electron microscopy and Fourier-transform infrared spectroscopy confirms their phase purity, morphology and surface chemistry, making them ideal for photocatalytic applications. The use of fruit juices eliminates hazardous chemicals, enhancing the biocompatibility and environmental sustainability of the process. Under UV light, $TbFeO_3$ nanostructures efficiently absorb radiation due to their narrow bandgap (around 2.1 eV), generating electron-hole pairs that drive the production of Reactive Oxygen Species (ROS) for dye degradation.

The photocatalytic mechanism of $TbFeO_3$ involves UV light absorption, which excites electrons from the valence band to the conduction band, creating electron-hole pairs. These interact with water and oxygen to form ROS, such as Hydroxyl Radicals (•OH) and Superoxide Radicals (O2•−), which effectively degrade the complex structures of organic dyes. The nanostructures achieve near-complete degradation of dyes like methylene blue within hours under UV irradiation, with efficiencies exceeding 90%. Their high surface area enhances dye adsorption, positioning pollutant molecules close to ROS for efficient breakdown. The magnetic properties of $TbFeO_3$, stemming from its iron component, enable easy separation from treated water using an external magnetic field, supporting catalyst recovery and reuse. Compared to conventional photocatalysts like TiO_2, $TbFeO_3$ offers superior UV responsiveness and stability, with minimal photocorrosion across multiple cycles. The green synthesis method reduces the environmental impact of production, aligning with sustainability goals. By optimizing parameters like juice concentration and calcination temperature, the photocatalytic performance of $TbFeO_3$ can be further enhanced, making it suitable for large-scale wastewater treatment [2].

Conclusion

The green synthesis of $TbFeO_3$ nanostructures using cherry and orange juice represents a breakthrough in sustainable photocatalysis for organic dye degradation. These eco-friendly nanostructures deliver high efficiency under UV light, combining a narrow bandgap, high surface area and magnetic separability to effectively degrade toxic dyes while enabling catalyst recyclability. This approach outperforms traditional photocatalysts in both performance and environmental impact, offering a scalable solution for wastewater treatment. As global water pollution challenges intensify, $TbFeO_3$ nanostructures provide a promising pathway for clean water initiatives, driving further innovation in green nanotechnology.

Acknowledgement

None.

Conflict of Interest

None.

References

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