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DEVELOPMENT AND APPLICATION OF YTTRIUM-BARIUM OXIDE (YBO) SEMICONDUCTORS FOR PHOTOCATALYTIC DEGRADATION OF ORGANIC DYES

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ABSTRACT

Provide a brief overview of the significance of photocatalytic degradation of organic dyes, the role of YBO semiconductors, and the key findings discussed in the review article**.**The research paper focuses on the development and application of yttrium-barium oxide (YBO) semiconductors, specifically Y2Ba3O6 (YB3O) and Y2Ba4O7 (YB4O), as robust photocatalysts for the degradation of organic dyes in wastewater under visible light. This report summarizes the key findings and insights from the paper, including the synthesis of YB3O and YB4O, their structural and optical characterization, photoelectrochemical properties, and their effectiveness in the photocatalytic degradation of organic dyes.0

Keywords: Yttrium – barium oxide**,** Visible light photocatalyst**,** Dye

INTRODUCTION

Water pollution is a critical environmental concern exacerbated by economic globalization and industrial modernization. One significant source of water contamination is organic dyes used in various industries. Efficient methods for treating dye-containing wastewater are essential to address this problem.

Photocatalysis, especially under visible light, has emerged as a promising technique for the removal of organic dyes from wastewater. While various photocatalysts have been explored, there is a need for materials that exhibit both high activity and stability.

Yttrium-barium-copper oxide (YBCO) is a well-known high-temperature superconductor with potential applications in photocatalysis. However, the paper highlights that YBCO's narrow bandgap limits its effectiveness as a photocatalyst. The presence of copper (Cu) in YBCO is identified as a key factor in its limited photocatalytic abilities.

To overcome these limitations, the research introduces the synthesis of YBO materials, specifically YB3O and YB4O, which are devoid of copper and offer wider bandgaps, thus improving their photocatalytic potential.

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MATERIALS AND METHODS

Synthesis of YB3O and YB4O

1. Preparation of raw materials: BaCO3 and Y2O3 were prepared by drying at 120°C for 48 hours.
2. Formation of precursors: Y2O3 and BaCO3 were combined in stoichiometric ratios for YB3O and YB4O.
3. Ball milling: The precursors underwent ball milling to ensure a homogeneous mixture.
4. Prefiring steps: Multiple prefiring steps were employed at specific temperatures, followed by grinding and sieving.
5. Sintering: The materials were sintered at high temperatures, and this process was repeated three times.
6. Magnetic separation: Iron chips generated during grinding were removed using magnetic separation.
7. Final ball milling: A final round of ball milling was conducted to obtain the

   YB3O and YB4O photocatalysts.

METHODOLOGY

Synthesis of YBO Semiconductors:

1. Raw materials, including BaCO3 and Y2O3, are prepared by drying them at 120°C for 48 hours.
2. Precursors of YB3O and YB4O are formed by weighing Y2O3 and BaCO3 in stoichiometric ratios.
3. The precursors are subjected to ball milling for 6 hours using zirconia grinding balls to obtain a homogeneous mixture.
4. The mixture undergoes two prefiring steps at specific temperatures and is ground and sieved between these steps.
5. The powdered material is sintered at higher temperatures, followed by grinding and sieving.
6. The sintering and powdering steps are repeated three times for material refinement
7. Magnetic separation is employed to remove iron chips generated during the grinding process.
8. Ball milling is carried out to obtain the final YB3O and YB4O photocatalysts

Characterization:

1. Various characterization techniques, including X-ray diffraction (XRD), SEM, TEM, EDS, and XRF, are employed to analyze the crystallographic, structural, and elemental properties of the materials.
2. Electrochemical tests, such as electrochemical impedance spectroscopy (EIS) and photocurrent response measurements, are conducted to assess the photoreaction of YBO materials.
3. Electron paramagnetic resonance spectroscopy (ESR) is used to verify the production of free radicals.
4. The band structures of YB3O and YB4O are determined using UV–Vis diffuse reflection spectroscopy (UV–Vis DRS).
5. Specific surface area measurements are carried out to determine the materials' reactivity and adsorption capacity.

Photocatalytic Degradation of Dyes

1. Photocatalytic experiments are conducted using a xenon lamp as the visible light source.
2. YB3O or YB4O photocatalyst is added to simulated wastewater containing Methylene Blue (MB) or Methyl Orange (MO) dyes.

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3. The dye solution is stirred in the dark to establish adsorption-desorption equilibrium.
4. The beakers are then exposed to visible light for photocatalytic degradation.
5. Samples are collected at specific time intervals, centrifuged, and the dye concentration in the supernatant is measured.
6. Sacrificial agents are employed to capture specific reactive species (hydroxyl radicals, superoxide radicals, and holes).
7. The reusability of YB3O and YB4O is tested over multiple cycles.

By following this methodology, the research aims to achieve its objectives and address the identified problem of water pollution due to organic dyes by developing and evaluating efficient photocatalytic materials.

Objectives

The primary objectives of this research paper are as follows:

Objective 1: Synthesis of YBO Semiconductors

To develop novel yttrium-barium oxide (YBO) semiconductors, specifically Y2Ba3O6 (YB3O) and Y2Ba4O7 (YB4O), by employing a copper-free solid-phase sintering method. This aims to create materials with enhanced structural stability and photocatalytic potential.

Objective 2: Characterization of YBO Materials

To comprehensively characterize the synthesized YB3O and YB4O materials through various techniques, including X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and energy-dispersive spectroscopy (EDS). This objective seeks to understand the crystallographic, structural, and elemental properties of the materials.

Objective 3: Investigation of Optical and Energy Band Properties

This is crucial for determining their suitability as photocatalysts under visible light and their potential to generate reactive species.

Objective 4: Evaluation of Photocatalytic Degradation

This objective focuses on their performance, selectivity, and their ability to produce reactive species for dye degradation.

Objective 5: Study of Recyclability and Stability

This objective aims to determine the long-term practicality of these materials in wastewater treatment applications.

RESULTS AND DISCUSSION

➢ ***Crystal and Microstructure***

Transmission electron microscopy (TEM) images further confirmed the layered structure of YBO materials, supporting their potential as photocatalysts.

➢ ***Elemental Composition***

Energy-dispersive spectroscopy (EDS) mapping demonstrated a uniform distribution of yttrium (Y) and barium (Ba) elements within the YB3O and YB4O materials. X-ray fluorescence spectroscopy (XRF) results verified that the sintered products matched their chemical formulas, confirming the synthesis of Y2Ba3O6 and Y2Ba4O7.

➢ ***Optical Characterization and Energy Band Analysis***

UV-Vis diffuse absorption spectra were used to examine the optical properties of YB3O and YB4O. The presence of multiple forbidden bands suggested that the materials were mixtures.

Forbidden band widths, estimated as 2.550 eV for YB3O and 2.583 eV for YB4O, indicated strong visible light absorption. The research also estimated the valence band tops and conduction band bottoms of YB3O and YB4O, which provide insights into the materials' potential to produce reactive species during photocatalysis.

- ***Photoelectrochemical Properties and Specific Surface Area***

Photogenerated current responses were tested, revealing fast and stable photocurrents with a response to switching illumination cycles. YB4O exhibited higher photocurrent responses and charge transfer efficiency compared to YB3O. Photoluminescence testing indicated that YB4O had a smaller peak than YB3O, suggesting a more efficient generation of electrons. This result was consistent with electrochemical barrier test results. Nitrogen adsorption isograms were used to measure the surface area of YB3O and YB4O. YB3O was found to have a larger specific surface area, indicating a higher number of reactive sites.

CONCLUSION

In conclusion, the findings in this research paper provide compelling evidence of YBO materials' potential as practical and efficient photocatalysts for wastewater treatment. The development of materials that can harness visible light to degrade organic dyes is a significant step forward in addressing water pollution caused by industrial processes. The materials' ability to produce various reactive species, as discussed in the paper, contributes to their efficacy in removing organic pollutants from wastewater, further emphasizing their importance in environmental conservation. The research presented in this paper opens avenues for future studies, including exploring potential modifications of YBO materials to enhance their photocatalytic activity and understanding the detailed mechanisms involved in the degradation of organic dyes. By combining insights from materials science and environmental engineering, researchers can contribute to the development of sustainable solutions for the global issue of water pollution.

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