

Abstract

Bismuth oxybromide (BiOBr) is a promising photocatalyst for clean energy utilization and environmental purification. However, its photocatalytic performance is limited by the rapid recombination of photogenerated charge carriers, which reduces the generation of reactive species. Improving its photocatalytic activity remains challenging. One effective approach is to develop BiOBr-based heterojunction systems. Additionally, the formation of bismuth-rich oxybromide (Bi₂₄O₃₁Br₁₀) has gained attention due to its easy synthesis, tunable morphology with controllable stoichiometry, and improved light absorption properties. In this research, BiOBr, Bi₂₄O₃₁Br₁₀ and BiOBr/Bi₂₄O₃₁Br₁₀ were hydrothermally synthesized using Bi(NO₃)₃·5H₂O and KBr as starting materials, with the suspension pH adjusted using NH₄OH. The results showed that pristine BiOBr was obtained at initial pH (pH 0.77). When the pH was adjusted to 9, pure Bi₂₄O₃₁Br₁₀ was formed, while the BiOBr/Bi₂₄O₃₁Br₁₀ heterojunction was produced at neutral pH (pH 7). The photocatalytic activity of these materials was evaluated by degrading organic pollutants, including rhodamine B (RhB) and ciprofloxacin (CIP), under visible-light irradiation. The BiOBr/Bi₂₄O₃₁Br₁₀ heterojunction exhibited the highest photodegradation efficiency for both pollutants. The heterojunction removed 99.06% of RhB, while BiOBr and Bi₂₄O₃₁Br₁₀ removed 52.07% and 81.96%, respectively. Similarly, for CIP, the heterojunction achieved a removal efficiency of 88.67%, compared to 63.68% with BiOBr and 68.35% with Bi₂₄O₃₁Br₁₀. The superior photocatalytic activity of the heterojunction is attributed to the effective visible-light absorption of BiOBr/Bi₂₄O₃₁Br₁₀ and the enhanced charge separation and migration efficiencies. Additionally, the heterojunction was tested for photocatalytic oxidation of arsenite (As(III)) at different solution pH levels, revealing enhanced oxidation efficiency in basic solutions.

Introduction

Single-component bismuth oxybromide

Layered structure

- slabs of [Bi₂O₂]²⁺ interleaved by double Cl⁻ layers.
- Generate internal electric field

Some drawbacks

- Poor visible light absorption
- Rapid recombination of electron-hole pairs

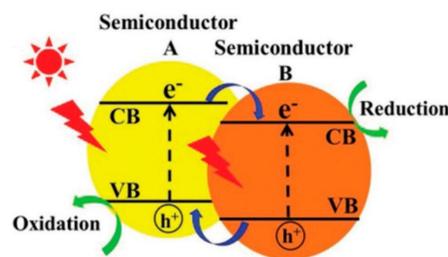


Fig. 1 Charge transfer pathway in Type II heterojunction.

Experiment procedure



Fig. 2 Preparation of BiOBr, BiOBr/Bi₂₄O₃₁Br₁₀ and Bi₂₄O₃₁Br₁₀.

Fig. 3 Experimental setup for the photocatalytic test.

Results and Discussion

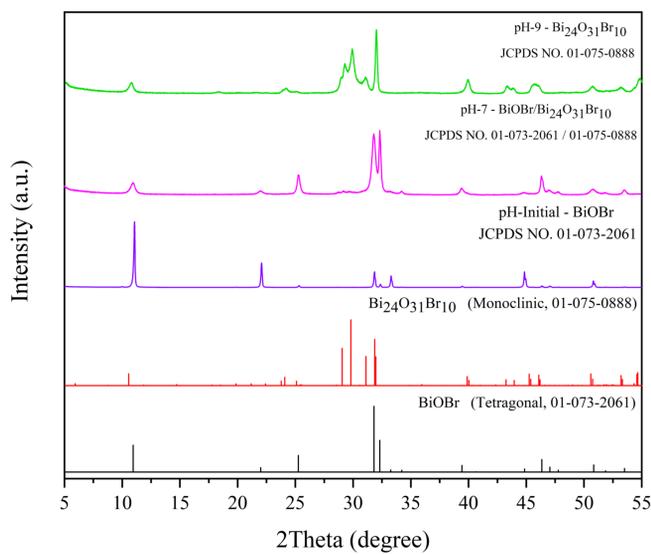


Fig. 4 XRD patterns of BiOBr, BiOBr/Bi₂₄O₃₁Br₁₀ and Bi₂₄O₃₁Br₁₀

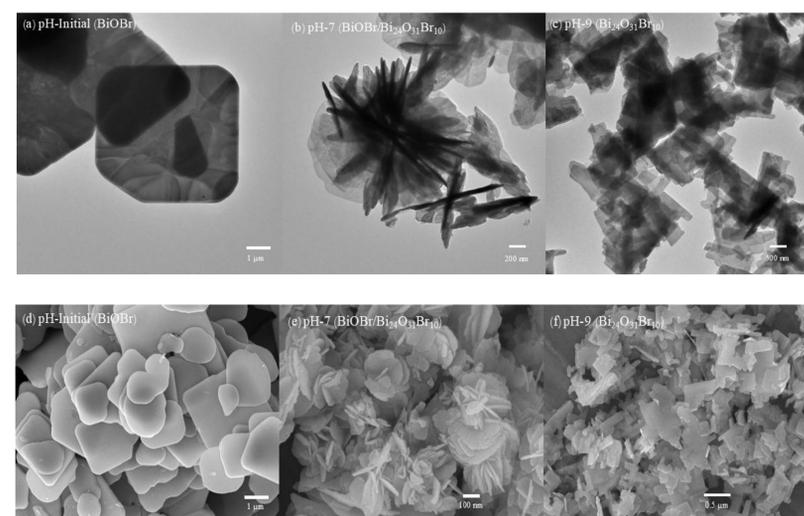


Fig. 5 (a-c) TEM images, (d-f) SEM images of the BiOBr, BiOBr/Bi₂₄O₃₁Br₁₀ and Bi₂₄O₃₁Br₁₀

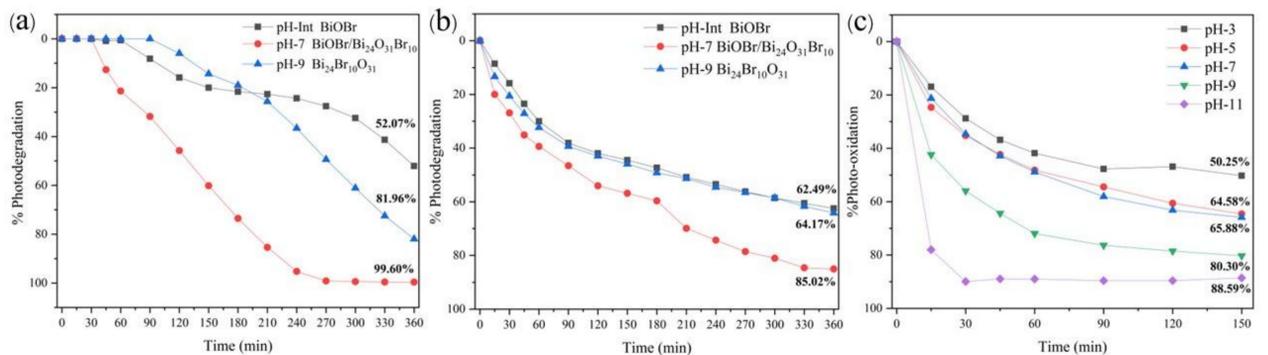


Fig. 6 Photodegradation efficiency of (a) RhB and (b) ciprofloxacin. (c) Photooxidation efficiency of As(III) at various pH solution

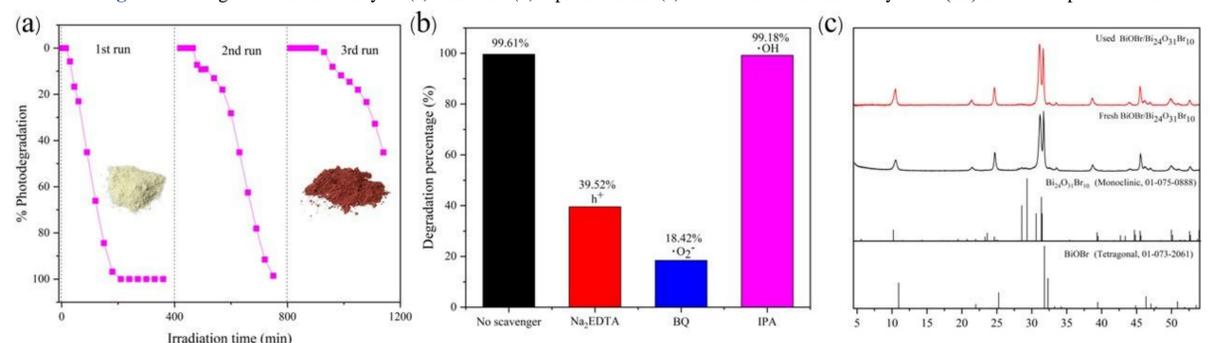


Fig. 7 (a) Recycling experiments for RhB photodegradation by BiOBr/Bi₂₄O₃₁Br₁₀. (b) Reactive species trapping experiments. (c) XRD patterns of fresh and used BiOBr/Bi₂₄O₃₁Br₁₀ photocatalysts after the 3rd run.

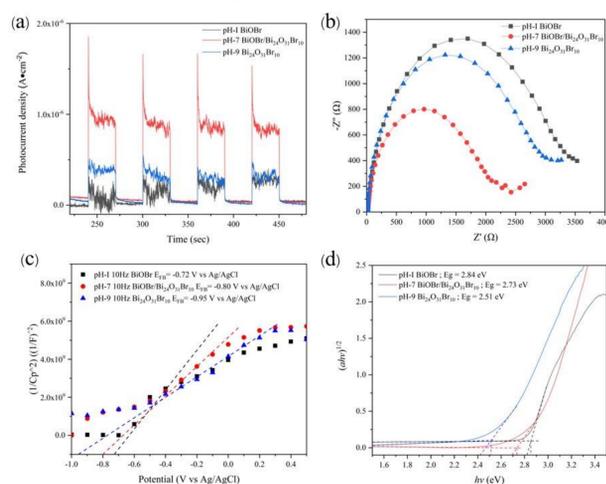


Fig. 8 (a) Photocurrent responses (b) EIS Nyquist plots (c) Mott Schottky plots and (d) Tauc plots of the BiOBr, BiOBr/Bi₂₄O₃₁Br₁₀ and Bi₂₄O₃₁Br₁₀ photocatalysts.

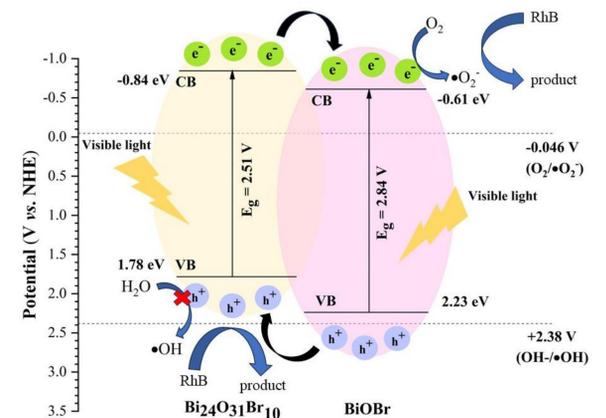


Fig. 9 Proposed photocatalytic mechanism in the BiOBr/Bi₂₄O₃₁Br₁₀ photocatalyst for degradation RhB.

Conclusion

BiOBr, Bi₂₄O₃₁Br₁₀ and BiOBr/Bi₂₄O₃₁Br₁₀ photocatalysts were successfully prepared using the hydrothermal method under varying the NH₄OH contents added. The BiOBr/Bi₂₄O₃₁Br₁₀ (pH-7) photocatalyst exhibited the greatest degradation of rhodamine B and ciprofloxacin; : 99.30% of rhodamine B and 85.02% of ciprofloxacin were removed. Trapping experiments identified that •O₂⁻ and h⁺ were responsible for the RhB photodegradation. Furthermore, this photocatalyst was able to oxidize As(III) at 88.59%. The photooxidation efficiency of As(III) was increased under basic solutions. The enhanced photocatalytic activity was ascribed to the close interfacial interactions between BiOBr and Bi₂₄O₃₁Br₁₀, which resulted in the formation of a Type-II heterojunction. This heterojunction facilitated efficient charge separation and migration, as evidenced by the electrochemical analysis.

Acknowledgements

This research project was funded by National Research Council of Thailand (NRCT) and Chiang Mai University: N42A650311. This research project was also supported by Fundament Fund 2025, Chiang Mai University and Thailand Science Research and Innovation (TSRI).

References

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