Enhanced Photo-Piezocatalytic Performance through Synergistic Effects for Silver-Modified $BaTiO_3/TiO_2$ Heterostructures

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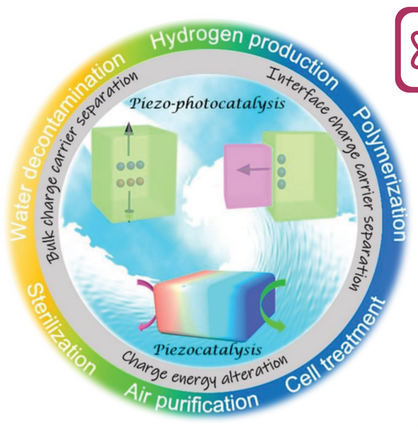
Abstract

With the substantial expansion of industrial scale, the pervasive pollution from organic contaminants increasingly threatens our daily lives and the environment. To address these issues, we propose an innovative approach combining photocatalysis and piezocatalysis for continuous degradation. By utilizing the hydrothermal synthesis technique, we produced a nanocomposite catalyst, Ag modified BTO/TiO_2, which is designed based on the photocatalytic properties of silver-modified titanium dioxide (TiO_2) and the piezocatalytic properties of barium titanate ($BaTiO_3$, BTO). By utilizing Ag-doped titanium dioxide as a structural template and meticulously adjusting the compositions, we can precisely tailor the Ag-modified BTO/TiO_2 heterostructures. It also varied the morphologies, crystal structures, further resulting in the related performance in organic dye degradation. Attributed to the synergistic effects of photocatalysis and piezocatalysis, the optimal photo-piezocatalyst demonstrates significantly enhanced catalytic performance under UV light irradiation and ultrasonic vibration. Compared to anatase TiO_2, the Ag modified BTO/TiO_2 under photo-piezocatalysis conditions achieves approximately 99% degradation efficiency in a 10.0 ppm methyl orange solution within 150 minutes. The calculated reaction rate constant (k) is 0.02540 min^{-1}, which is 3.3 and 1.7 times higher than that under the photocatalysis and piezocatalysis. This indicates that the integration of BTO and TiO_2 facilitates an efficient charge transfer route, while ultrasonic vibration additionally enhances the reaction in the BTO/TiO_2 heterostructure, serving as a nanogenerator.

Introduction

Advantages of Photo-Piezocatalysis



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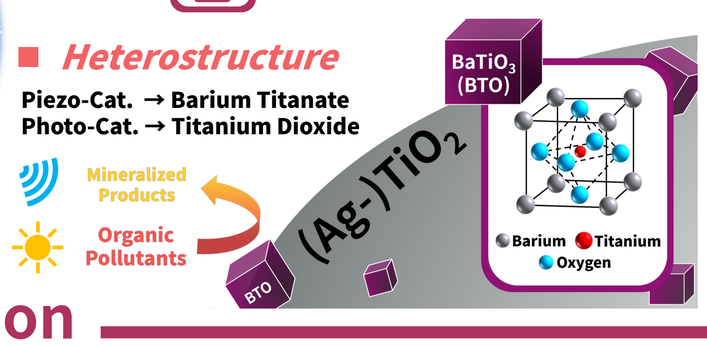
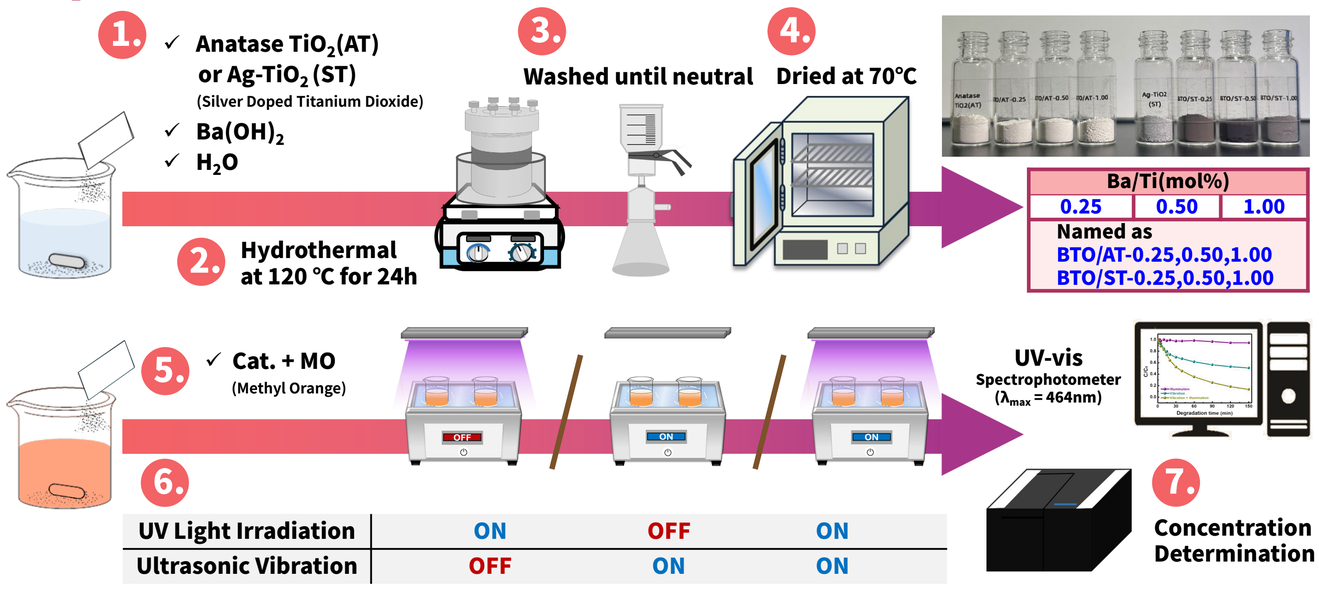
- **Boosting Charge Separation**
- **Greater Flexibility and Applicability**
- **Environmentally Friendly**

Heterostructure

Piezo-Cat. → Barium Titanate
Photo-Cat. → Titanium Dioxide



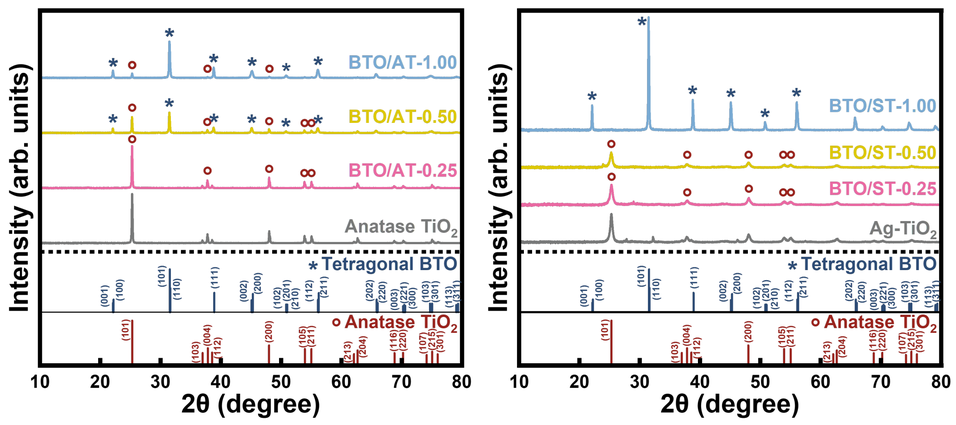
Experimental



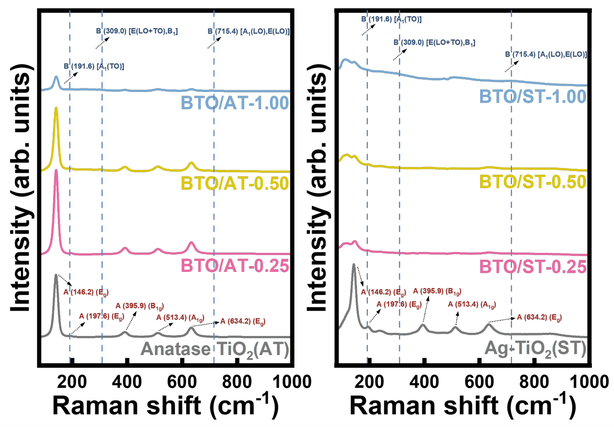
Characterization

Crystal Structure Analysis

XRD Patterns

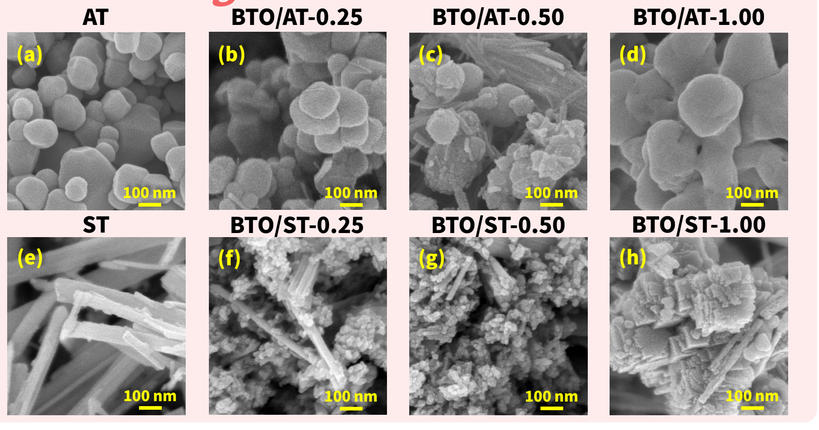


Raman Spectra



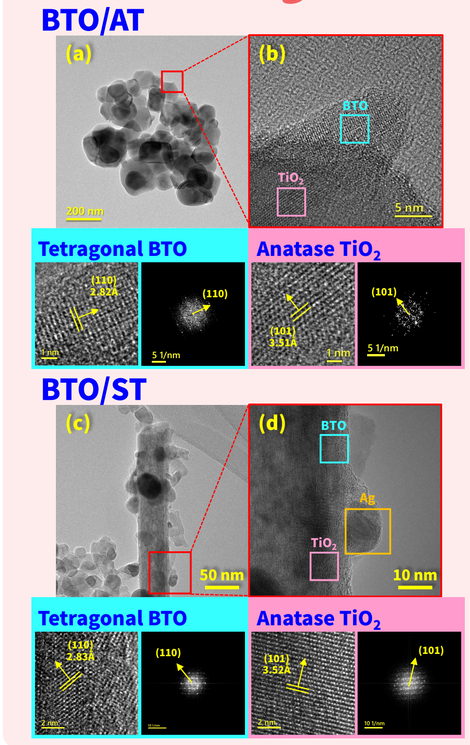
Morphology

SEM Images

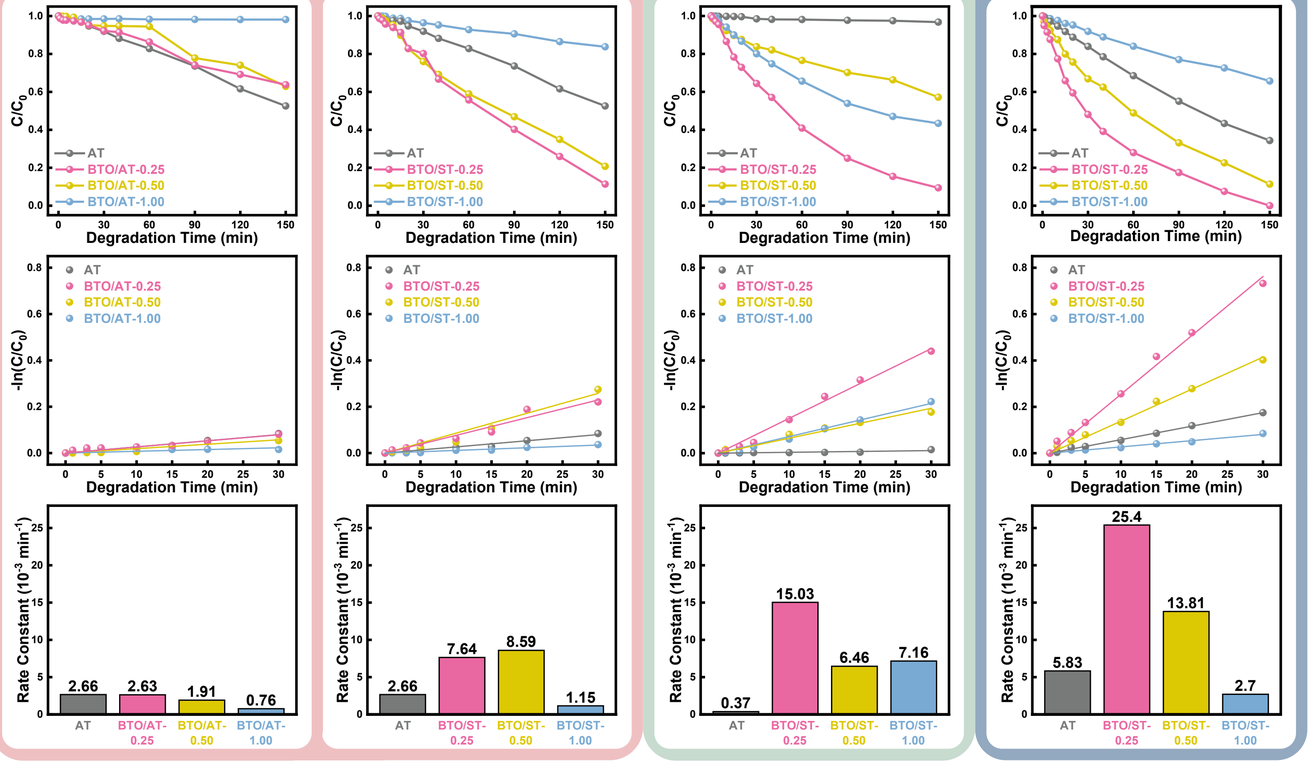


Morphology

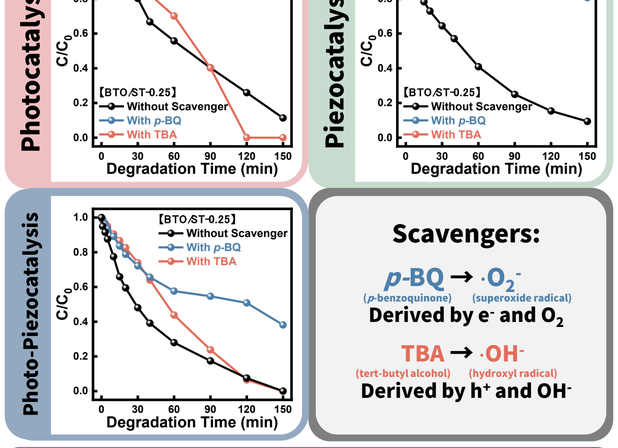
HRTEM Images



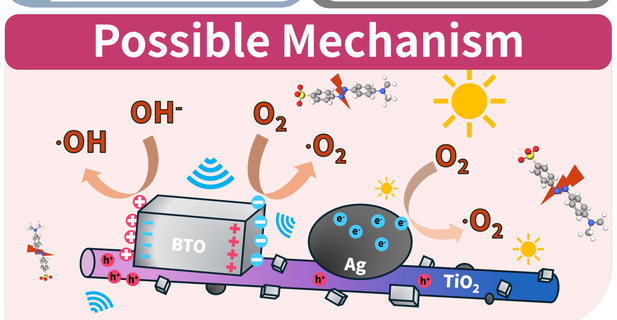
Catalytic Degradation Performance



Reactive Oxygen Species



Possible Mechanism



Conclusion

- A series of BTO/TiO_2 photo-piezocatalysts were synthesized using the hydrothermal method, and their material characteristics and catalytic efficiencies were thoroughly examined.
- The optimal BTO/TiO_2 photo-piezocatalyst, derived from silver doped anatase TiO_2 with a Ba/Ti ratio of 0.25, exhibited superior performance in degrading methyl orange, with a 99% efficiency rate—4.4 times more effective than anatase TiO_2.
- By utilizing titanium dioxide as a template and enabling the in-situ growth of small barium titanate on it, the photo-piezocatalyst exhibits significant carrier migration ability and effectively reduces carrier recombination.
- Through reactive oxygen species (ROS) analysis, we proposed the possible mechanism of photo-piezocatalytic reaction, inferring the superoxide radicals induced by negative charges dominate the both catalytic activities.

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