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Enhancing Photocatalytic Activity of Oxygen Vacancies-Rich Tungsten Trioxide (WO_3) for Sustainable Energy Conversion and Water Purification

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Abstract : The demand for sustainable and efficient energy conversion using solar energy has grown rapidly in recent years. In this pursuit, solar-to-chemical conversion has emerged as a promising approach, with oxygen vacancies-rich tungsten trioxide (WO_3) playing a crucial role. This study presents a method for synthesizing oxygen vacancies-rich WO3, resulting in a significant enhancement of its photocatalytic activity, representing a significant step towards sustainable energy solutions. Experimental results underscore the importance of oxygen vacancies in modifying the properties of WO_3. These vacancies introduce additional energy states within the material, leading to a reduction in the bandgap, increased light absorption, and acting as electron traps, thereby reducing emissions. Our focus lies in developing oxygen vacancies-rich WO_3, which demonstrates unparalleled potential for improved photocatalytic applications. The effectiveness of oxygen vacancies-rich WO_3 in solar-to-chemical conversion was showcased through rigorous assessments of its photocatalytic degradation performance. Sunlight irradiation was employed to evaluate the material's effectiveness in degrading organic pollutants in wastewater. The results unequivocally demonstrate the superior photocatalytic performance of oxygen vacancies-rich WO_3 compared to conventional WO_3 nanomaterials, establishing its efficacy in sustainable and efficient energy conversion. Furthermore, the synthesized material is utilized to fabricate films, which are subsequently employed in immobilized WO_3 and oxygen vacancies-rich WO_3 reactors for water purification under natural sunlight irradiation. This application offers a sustainable and efficient solution for water treatment, harnessing solar energy for effective decontamination. In addition to investigating the photocatalytic capabilities, we extensively analyze the structural and chemical properties of the synthesized material. The synthesis process involves in situ thermal reduction of WO_3 nano-powder in a nitrogen environment, meticulously monitored using thermogravimetric analysis (TGA) to ensure precise control over the synthesis of oxygen vacancies-rich WO_3. Comprehensive characterization techniques such as UV-Vis spectroscopy, X-ray photoelectron spectroscopy (XPS), FTIR, Raman spectroscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM), and selected area electron diffraction (SAED) provide deep insights into the material's optical properties, chemical composition, elemental states, structure, surface properties, and crystalline structure. This study represents a significant advancement in sustainable energy conversion through solar-to-chemical processes and water purification. By harnessing the unique properties of oxygen vacancies-rich WO_3, we not only enhance our understanding of energy conversion mechanisms but also pave the way for the development of highly efficient and environmentally friendly photocatalytic materials. The application of this material in water purification demonstrates its versatility and potential to address critical environmental challenges. These findings bring us closer to a sustainable energy future and cleaner water resources, laying a solid foundation for a more sustainable planet.

Keywords : sustainable energy conversion, solar-to-chemical conversion, oxygen vacancies-rich tungsten trioxide (WO_3), photocatalytic activity enhancement,water purification
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