ABSTRACT

THESIS: Tuning the Band Gap of Bismuth Vanadate via Z-Scheme Heterojunction

STUDENT: Gbemisola J. Bamiduro

DEGREE: Master of Science

COLLEGE: Sciences and Humanities

DATE: July 2021

PAGES: 106

Metal oxide semiconductors such as TiO$_2$ and ZnO have been exploited many times in photocatalysis and photoelectrochemical applications under UV light irradiation. Alternatively, new sets of metal oxide semiconductors such as Cu$_2$O, Fe$_2$O$_3$, and BiVO$_4$ have attracted widespread attention because of their ability to absorb light in the visible region. However, most of this category of photocatalyst is impacted by electron-hole recombination, slow charge transportation, and photo-corrosion. Furthermore, the bandgap of most metal oxides is not positioned to allow the reduction of water to hydrogen. Creating a Z-scheme heterojunction is a practical approach to total photoelectrochemical water splitting by combining a photoanode and a photocathode in one photocatalyst. This architecture allows spatial separation between the H$_2$ and the O$_2$ generation processes and improves the electron/hole separation. In this thesis, we describe a new approach to enhance the photocatalytic activity of BiVO$_4$ with other bismuth-based metal oxides, namely Bi$_2$Ru$_2$O$_7$ and Bi$_x$Ga$_y$O$_z$ to produce the Z-scheme photocatalyst Bi$_2$Ru$_2$O$_7$/BiVO$_4$ and Bi$_x$Ga$_y$O$_z$/BiVO$_4$, respectively. These heterogeneous Z-scheme architectures are constructed by temperature-controlled hydrothermal synthetic methods. A relatively low-temperature
hydrothermal synthesis at 80 °C and high-temperature hydrothermal synthesis at temperatures ranging from 140 to 180 °C have been followed to tune the composition of the BiVO₄-based Z-scheme photocatalysts. These materials are further characterized by transmission electron microscopy, x-ray crystallographic diffraction, x-ray photoelectron spectroscopy, and UV-vis diffuse reflectance spectroscopy. Among all the nano-heterojunction materials, the Bi₂Ru₂O₇/BiVO₄ Z-scheme heterojunction displayed an improved photocatalytic activity in the degradation of the organic dye, rhodamine B. The Bi₂Ru₂O₇/BiVO₄ heterojunction degrades rhodamine B completely in 80 min compared to 300 min and 120 min for the single oxides Bi₂Ru₂O₇ and BiVO₄, respectively. The photoelectrochemical characterization indicated that the Z-scheme heterojunction improved the charge transfer and enhanced the electron/hole separation in Bi₂Ru₂O₇/BiVO₄ photocatalyst compared to the single catalyst. This novel bismuth vanadate/bismuth heterometal composite is a promising photocatalyst for photoelectrochemical water splitting and photodegradation of persistent organic contaminants.