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MXene Mediated Layered 2D-3D-2D g-C3N4@WO3@Ti3C2 Multijunctional Heterostructure with Enhanced Photoelectrochemical and Photocatalytic Properties

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Abstract : In recent years, advancement in the field of nanotechnology has evolved new strategies to address energy and environmental issues. Amongst the developing technologies, visible-light-driven photocatalysis is regarded as a sustainable approach for energy production and environmental detoxifications, where transition metal oxides (TMOs) and metal-free carbon-based semiconductors such as graphitic carbon nitride (CN) evidenced notable potential in this matter. Herein, g-C_3N_4@WO_3@Ti_3C_2Tx three-component multijunction photocatalyst was fabricated via facile ultrasonic-assisted self-assembly, followed by calcination to facilitate extensive integrations of the materials. A series of different Ti_3C_2 wt% loading in the g-C_3N4@WO_3@Ti_3C_2Tx were prepared and represented as 1-CWT, 3-CWT, 5-CWT, and 7-CWT corresponding to 1, 3, 5, and 7wt%, respectively. Systematic characterization using spectroscopic and microscopic techniques were employed to validate the successful preparation of the photocatalysts. Enhanced optoelectronic and photoelectrochemical properties were observed for the WO_3@Ti_3C2@g-C_3N4 heterostructure with respect to the individual materials. Photoluminescence spectra and Nyquist plots show restrained recombination rates and improved photocarrier conductivities, respectively, and this was credited to the synergistic coupling effect and the presence of highly conductive Ti_3C2 MXene. The strong interfacial contact surfaces upon the formation of the composite were confirmed using XPS. Multiple charge transfer mechanisms were proposed for the WO3@$Ti3C_2$@g-C3N4, which couples Z-scheme and Schottky-junction mediated with Ti3C2 MXene. Bode phase plots show improved charge carrier life-times upon the formation of the multijunctional photocatalyst. Moreover, transient photocurrent density of 7-CWT is 40 and seven (7) times higher compared to that of g-C_3N4 and WO3, correspondingly. Unlike in the traditional Z-Scheme, the formed ternary heterostructure possesses interfaces through the metallic 2D Ti_3C_2 MXene, which provided charge transfer channels for efficient photocarrier transfers with carrier concentrations (ND) of 17.49×1021 cm-3 and 4.86% photo-to-chemical conversion efficiency. The as-prepared ternary g-C_3N_4@WO_3@Ti_3C_2Tx exhibited excellent photoelectrochemical properties with reserved redox band potential potencies to facilitate efficient photo-oxidation and -reduction reactions. The fabricated multijunction photocatalyst exhibits potentials to be used in an extensive range of photocatalytic process vis., production of valuable hydrocarbons from CO_2, production of H_2, and degradation of a plethora of pollutants from wastewater.

Keywords : photocatalysis, Z-scheme, multijunction heterostructure, Ti_3C_2 MXene, g-C_3N_4
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