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Catalytic Synergy via Optimized MoS_2-WS_2 Heterostructure Supported on Nitrogen-Doped Reduced Graphene Oxide for Enhanced Hydrogen Generation in Acidic Medium

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Abstract

Tungsten disulfide (WS_2) has shown promise as a catalyst for the hydrogen evolution reaction (HER), and doping it with transition metals (e.g., Mo) can further boost its activity. In this study, we synthesized MoS_2-WS_2 heterostructure supported on nitrogen-doped reduced graphene oxide (N-rGO) using a hydrothermal method, testing MoS_2 concentration(w/w) levels at 5%, 10%, and 20% to optimize HER performance. Raman spectroscopy and SEM confirmed the successful formation of MoS_2-WS_2/N-rGO composites, with Raman spectra revealing four characteristic peaks: 420 cm^{-1} (A_{1g} mode of WS_2), 380 cm^{-1} (E^1_{2g} mode of MoS_2), and D and G bands of N-rGO at 1,360 cm^{-1} and 1,600 cm^{-1}, respectively. Additionally, the peak heights of MoS_2 and WS_2 are influenced by the incorporating concentration of MoS_2. SEM images showed a structural shift from irregular flakes to granular and flower-like particles with increased MoS_2 concentration, and the presence of MoS_2 is responsible for the formation of flower-like particles. Electrochemical HER testing in 0.5 M H_2SO_4 demonstrated that 10% MoS_2-WS_2/N-rGO achieved the lowest overpotential (-177.6 mV at -10 mA cm^{-2}) and smallest Tafel slope (73.40 mV dec^{-1}), compared to 5% (-292.3 mV; 101.8 mV dec^{-1}) and 20% (-284.9 mV; 92.9 mV dec^{-1}). The Tafel slope of 10% MoS_2-WS_2/N-rGO suggests balanced Volmer and Tafel contributions. Double layer capacitance (C_{dl}) of 5%, 10%, and 20% MoS_2-WS_2/NrGO, as determined by the CV method, is 2.72, 5.71, and 1.17 mF cm^{-2}, respectively. The corresponding electrochemical active surface areas (ECSAs) measured are 136, 285.5, and 58.5 cm^2. This indicates that a 10% (w/w) concentration of MoS_2 provides optimal active surface area, highlighting its superior HER performance in acidic media.

Keywords: *Hydrogen evolution reaction, Water splitting, MoS_2 doping, WS_2, Electrocatalyst*