ENHANCED ELECTROCATALYTIC HER PERFORMANCE: A COMPARATIVE STUDY OF OPTIMIZED BINARY AND TERNARY ELECTROCATALYSTS IN ALKALINE FRESHWATER AND SEAWATER

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The electrocatalytic activity of two optimized, non-noble transition metal-based 3D bimetallic and trimetallic coatings (electrocatalysts) for hydrogen evolution (HER) in alkaline freshwater and seawater was investigated in this comparative study. Both electrodes were fabricated using a facile and inexpensive electrochemical deposition method based on the dynamic hydrogen bubble template (DHBT) technique. The electrodes were characterized using scanning electron microscopy with energy-dispersive X-ray spectroscopy, and inductively coupled plasma optical emission spectroscopy. Their HER performance was evaluated using linear sweep voltammetry at different temperatures in alkaline freshwater (1.0 M KOH), simulated seawater, SSW (1.0 M KOH + 0.5 M NaCl) and alkaline seawater, ASW (1.0 M KOH + natural seawater). A thin titanium (Ti) foil (0.127 mm thickness) was used as the substrate for synthesizing these binder-free, self-supported NiMn and NiMnCo electrocatalysts. The optimized binary NiMn/Ti-5 electrocatalyst's surface morphology exhibits a unique microsized porous architecture with abundant pores of distinctly different sizes. In contrast, the optimized ternary NiMnCo/Ti-2 electrocatalyst demonstrates a cauliflower-like, curd-shaped microspherical architecture that is directly deposited on the substrate. These compactly grown microspheres uniformly cover the entire surface of the conductive Ti substrate.

From the comparative perspective, the optimized NiMnCo/Ti-2 electrocatalyst exhibits excellent HER activity in alkaline media, achieving a low overpotential of 66 mV at the benchmark current density of 10 mA/cm^2. In contrast, the optimized NiMn/Ti-5 electrocatalyst requires a relatively higher overpotential of 127 mV to reach the same current density. In simulated seawater and alkaline seawater, the required overpotentials decreased significantly for both binary and ternary electrodes. Specifically, the 3D NiMn/Ti-5 electrode exhibited overpotentials of 64 mV (SSW) and 79 mV (ASW), whereas the 3D NiMnCo/Ti-2 electrocatalyst required only 29 mV (SSW) and 59 mV (ASW). These synthesized non-noble metal-based optimized binary and ternary electrocatalysts also demonstrated excellent long-term stability at a constant potential of -0.232 V (vs. RHE) and a constant current density of 10 mA/cm^2 showing exceptional current retention and minimal potential fluctuation. Furthermore, multi-step chronopotentiometric measurements were performed in alkaline media and SSW within a current density range of 20 mA/cm^2 to 100 mA/cm^2 for the optimized NiMnCo/Ti-2 electrocatalyst. The results confirm its sustainable durability and suitability for practical alkaline freshwater and seawater electrolysis applications.

Keywords: 3D Electrocatalyst, Hydrogen Evolution Reaction (HER), Simulated Seawater, Alkaline Seawater