Synergetic Optimization via Composition-Dependent Nanostructuring in Co-Mo-S Electrocatalysts for Efficient Hydrogen Evolution in Alkaline Solution

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Earth-abundant metal sulfides attracts large attention in recent years for hydrogen production via electrocatalytic water splitting. However, most works have been limited to the acidic condition, whereas the hydrogen evolution reaction (HER) in alkaline condition has rarely been discussed. Here we present an effective strategy for the growing of Co-Mo-S catalysts on carbon cloth via the controllable incorporation of cobalt into MoS₂ with L-cysteine and phosphomolybdic acid to achieve the synergistic interaction of CoS₂ and MoS₂. The optimized Co-Mo-S catalysts (Co:Mo=1:2) showed a largely improved HER activity with an overpotential of 92 mV at current density of 10 mA cm⁻² and Tafel slope of 82 mV dec⁻¹. The origin of the activity enhancement was investigated through a series of characterizations, where the synergetic effect of the intrinsic fast HER kinetics of metallic CoS₂ and the high active surface area of MoS₂ plays a crucial role. With appropriate amount of cobalt, the Co-Mo-S catalysts show a relatively uniform distribution on the carbon cloth to ensure the large surface area, whereas excessive cobalt results in the formation of the large CoS₂ particles with low HER activity from the low active surface area. Further electrochemical measurements demonstrated that the combination of larger exchange current density of CoS₂ and the high electrochemical double-layer capacitance (proportional to the active surface area) of MoS₂ together contributed to the HER activity enhancement of the Co-Mo-S catalysts. The Co-Mo-S/CC catalysts also show robust stability in alkaline solution. Our work provides a more profound understanding and an interesting view for the design of efficient ternary transition metal sulfide HER catalysts in alkaline condition by synergetic optimization of the intrinsic HER kinetics and the electrochemical active surface area.

Keywords: molybdenum sulfide; cobalt sulfide; carbon cloth; hydrogen evolution reaction; alkaline solution

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