Enhancing Green Hydrogen Production Using Magnetocaloric-Activated Electrocatalysis

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Global fossil fuel combustion emits 40 billion metric tons of CO2 annually, driving climate change and energy insecurity. Renewable-powered water electrolysis offers a sustainable pathway to green hydrogen as a clean energy carrier. However, conventional systems lose up to 40% of input energy due to sluggish oxygen evolution reaction kinetics and gas bubble accumulation. This project introduces a magnetocaloric-assisted electrocatalysis strategy enabling localized thermal enhancement under a magnetic field (MF) without external heating or redesign. A gadolinium-based magnetocaloric alloy (Gd–Fe–Co–Cu) was electrodeposited onto nickel foam, forming a high-surface-area, magnetically responsive electrode. Repeatability was confirmed across more than 10 trials. Electrochemical performance was evaluated in alkaline electrolyte using linear sweep voltammetry, electrochemical impedance spectroscopy, gas chromatography, and 50-hour stability testing with and without a MF. At 2.0 V, the catalyst achieved a current density of 780 mA cm?^{2}, exceeding benchmark RuO2 by over 50%. Under magnetic activation, the required potential decreased from 1.40 V to 1.26 V (10% reduction), while hydrogen production increased by ~50% relative to no MF, reaching ~500 µmol within 60 minutes with near-unity Faradaic efficiency ~99%. Charge transfer and solution resistances decreased by ~30% with a MF. No measurable degradation was observed over 50 hours, confirming durability under magnetic activation. Material costs are 31% lower than RuO2, reducing hydrogen production costs to \$4.60 kg?^{1} vs \$5.50 kg?^{1} and lowering energy consumption by 33%. These results demonstrate the potential of magnetocaloric-assisted electrocatalysis as a scalable and energy-efficient strategy for green hydrogen production.

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