Synergistic Effect of Laser Surface Modification and NiCoMn Electrodeposited Novel Electrode for Efficient Green Hydrogen Generation

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Dependence on fossil fuels is driving climate change and environmental damage, creating an urgent need for cleaner alternatives. Hydrogen, as a sustainable and carbon-free fuel, offers a promising solution for the future of energy. However, the global shift to green hydrogen is limited by non-noble metal catalysts, which often have low activity and poor stability for the hydrogen evolution reaction (HER). This study introduces a new approach that combines pulse laser patterning with an electrodeposition method to improve hydrogen production. The laser patterning process was employed to tailor the surface morphology and structural characteristics of the copper foil (CF) as a metallic support. This created micro and nanoscale surface features on the copper foil, which increased the number of active sites and improved the electron transfer. Ternary NiCoMn electrocatalysts were deposited onto unmodified and laser-modified copper foil using electrodeposition, creating NiCoMn@CFun-mod and NiCoMn@CFmod. Characterization via XRD, SEM, and XPS confirmed the material synthesis, while electrochemical performance was evaluated through CV, EIS, and chronopotentiometry. The NiCoMn@CFmod electrode exhibited superior HER performance, requiring only 149 mV to achieve a current density of -10 mA·cm?², compared to NiCoMn@CFun-mod (246 mV), CFmod (216 mV), and CFun-mod (300 mV). It also showed a low charge transfer resistance of 4.6 O, maintained stable performance for 30 hours at -10 mA·cm?², and achieved a Faradaic efficiency greater than 90%. These results demonstrate a highly efficient, stable, and scalable electrocatalyst strategy for green hydrogen production, offering a potentially practical pathway toward sustainable and cost-effective energy.

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