IMPERIAL

High Performance Electrospun NiFe Electrodes for Anion Exchange Membrane Water Electrolysis

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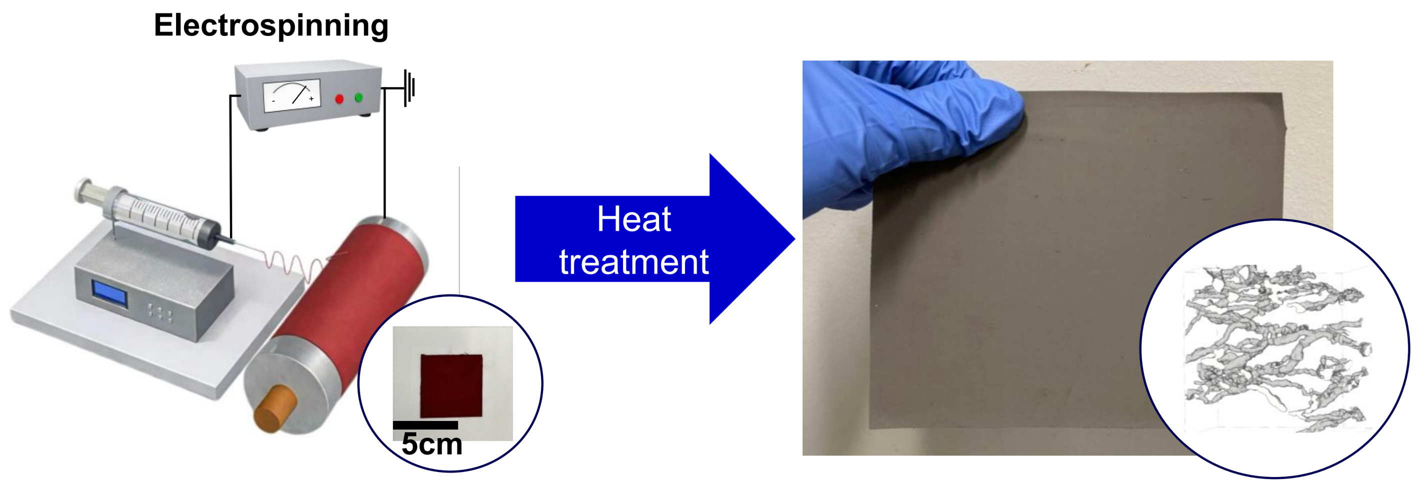
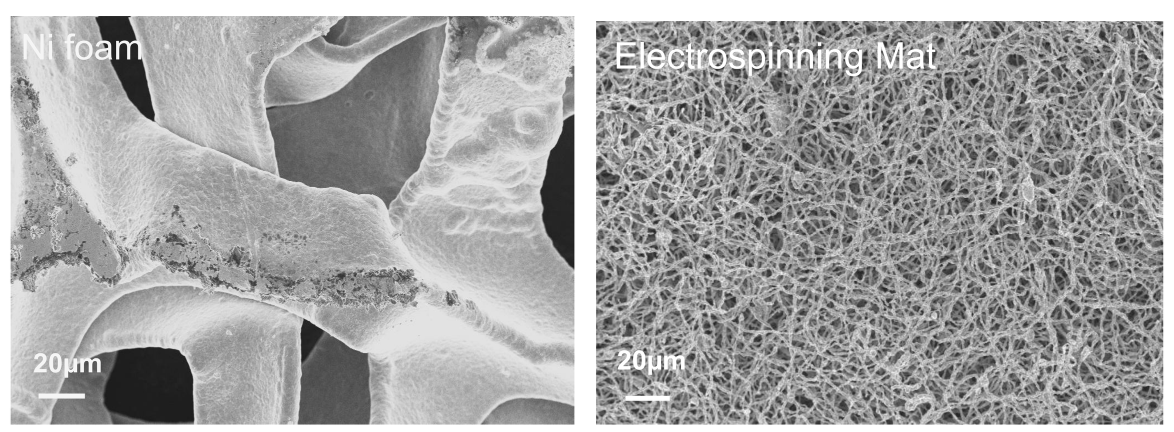
INTRODUCTION

The development of high-performance and low-cost electrodes is critical for advancing anion exchange membrane water electrolysis(AEMWE) towards industrial-scale hydrogen production. Conventional porous metal electrodes, such as nickel foam, are widely used but are fundamentally limited by relatively low surface area, coarse pore structures, and inefficient catalyst utilisation at high current densities. These limitations restrict mass transport, increase energy losses, and ultimately hinder device performance under practical operating conditions.

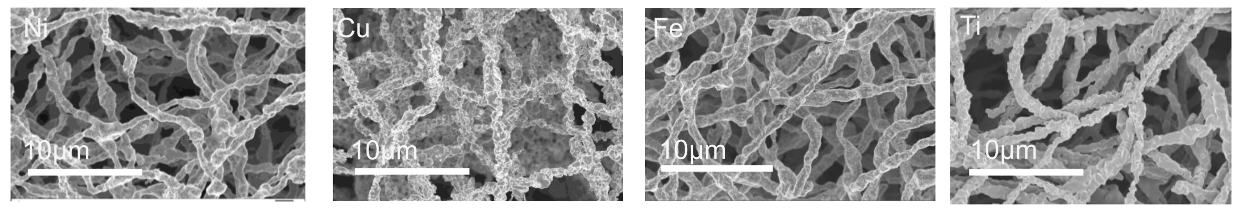
Electrospinning is a scalable and versatile technique capable of producing continuous fibrous materials with nanoscale feature sizes and ultrahigh porosity. Here, we demonstrate—for the first time—the scalable production of continuous metallic fibre mats via electrospinning



This approach enables the formation of highly porous (>90%) three-dimensional networks with more than 1000 times higher surface area than conventional nickel foam. Electrospinning offers a unique combination of structural tunability, high surface area, and compatibility with large-scale production. These advantages position electrospun metallic fibre electrodes as a transformative platform for next-generation, low-cost, and high-performance water electrolysis systems.

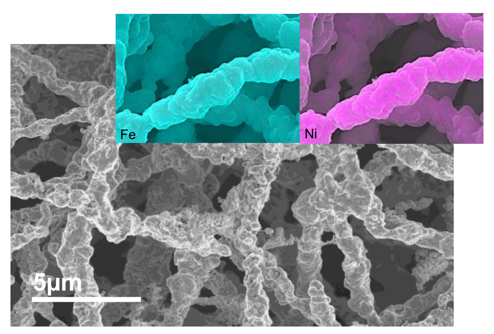


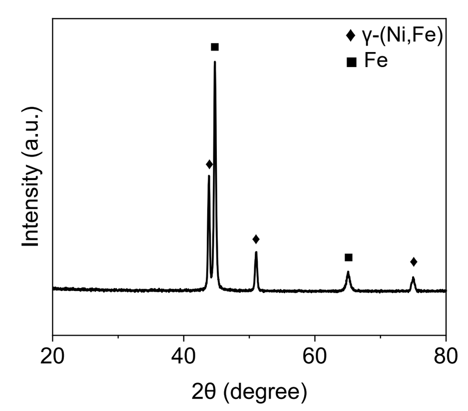
Importantly, this electrospinning strategy is highly versatile and broadly applicable. We have successfully extended this approach to fabricate a range of pure metallic fibre networks, including Ni, Fe, Cu, Ti, and Co, as well as multi-component alloy systems, demonstrating its generality for scalable porous metal manufacturing.



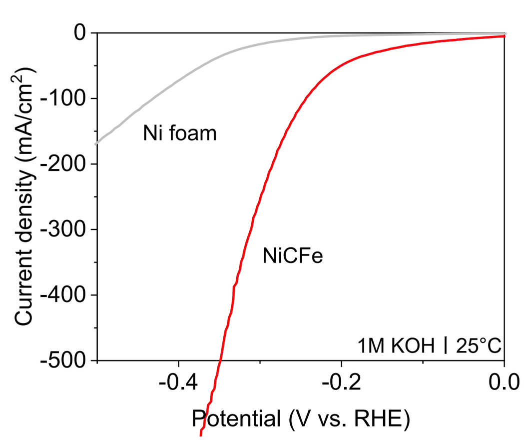
Main

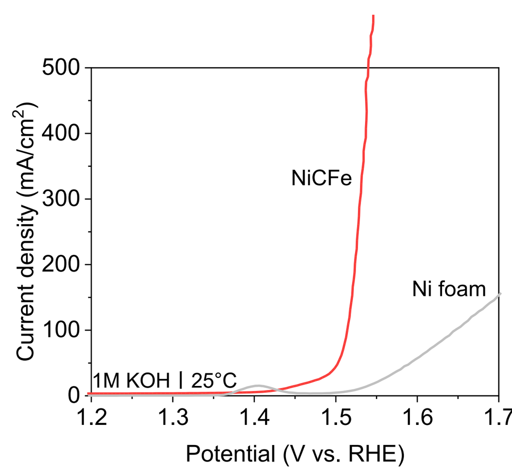
Iron is selected as the primary structural material due to its earth abundance, low cost, and excellent mechanical robustness, making it highly attractive for large-scale electrode manufacturing. However, its poor catalytic activity and susceptibility to oxidation limit its direct application in alkaline water electrolysis. To address these challenges, a NiFe surface alloy was introduced via a scalable coating and thermal alloying strategy. This results in a low-cost, electrospun iron-based porous electrode coated with a conformal NiFe alloy layer, forming a highly efficient bifunctional platform for both the oxygen evolution reaction (OER) and hydrogen evolution reaction (HER).



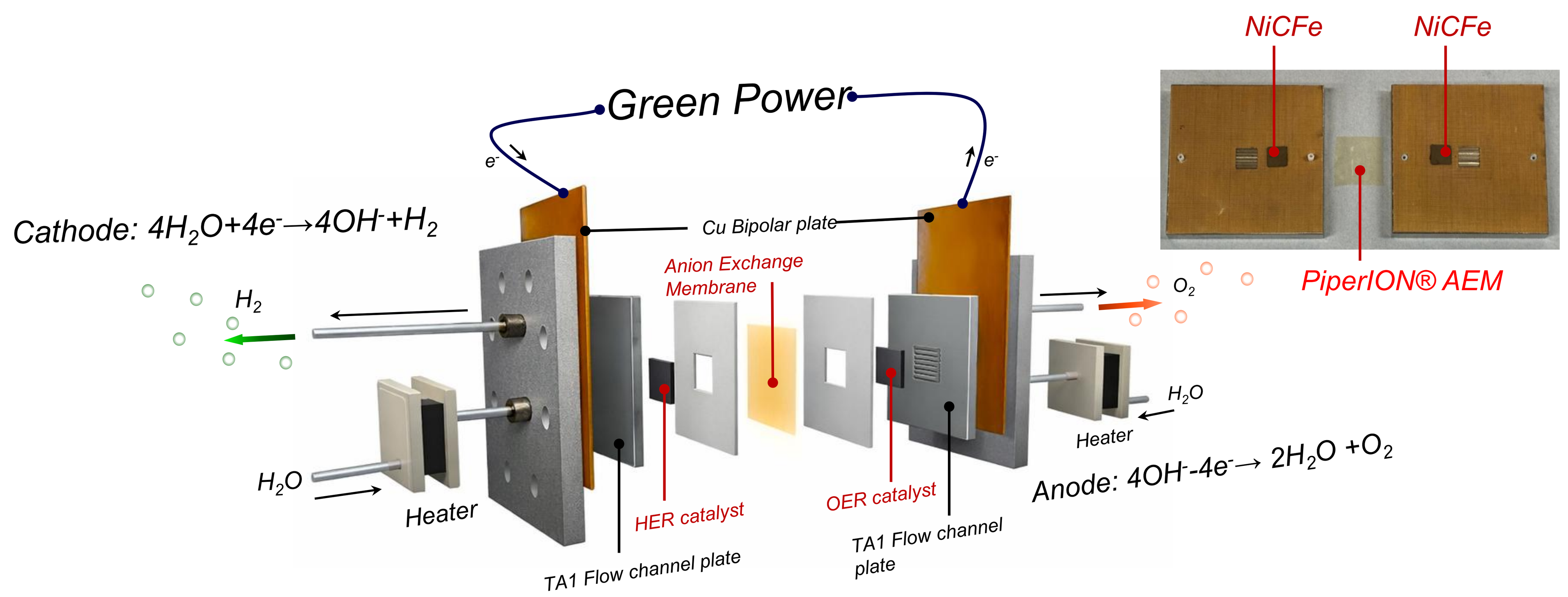


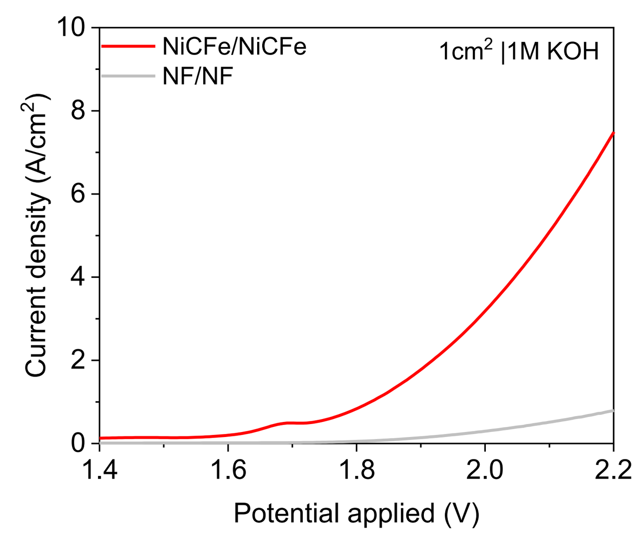
Ni coated Fe (NiCFe) mat exhibits outstanding OER activity without any additional catalyst, achieving a low overpotential of ~290 mV at 500 mA cm⁻². The electrode delivers an ultrahigh ECSA (258 m² g⁻¹), demonstrating exceptional catalyst utilisation enabled by the electrospun architecture. NiCFe also shows significantly improved performance compared to Ni foam due to its high surface area and fully interconnected porous structure.

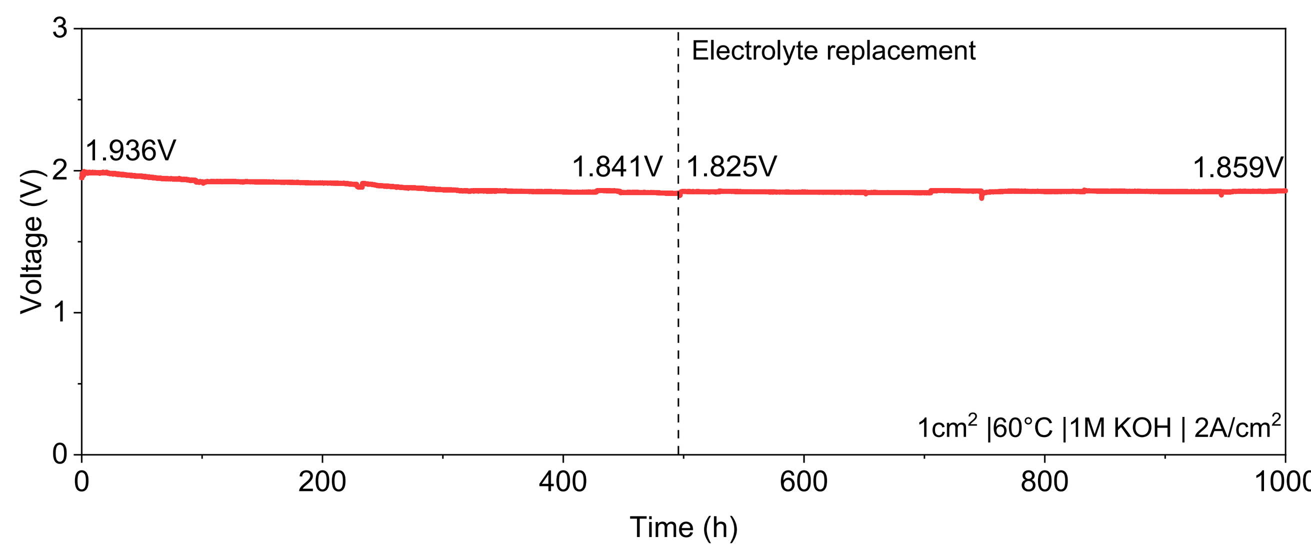




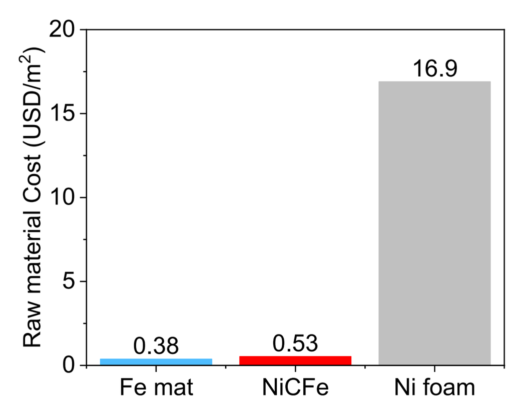
NiCFe was evaluated as both anode and cathode in a 1 cm² AEM electrolyzer. Benefiting from its highly interconnected porous structure and large surface area, the substrate enables efficient electrolyte penetration, rapid bubble removal, and enhanced mass transport under flow-cell conditions. At 60 °C, the cell achieves 2.3 V at 10 A cm⁻². The NiCFe electrolyzer operates stably for over 1000 h at 2 A cm⁻². The fully activated cell reaches 4.69 A cm⁻² at 2.0 V. This high performance is achieved without any additional catalyst loading, surpassing most reported bifunctional non-precious electrolyzer systems.







Compared to nickel foam, NiCFe demonstrates markedly superior performance under flow conditions, enabled by its fully interconnected porous architecture, ultrahigh surface area, and more efficient electrolyte penetration and gas bubble removal.



Importantly, the NiCFe electrode offers a significant cost advantage, with raw material costs (~0.53 USD m⁻²) only ~3.1% of nickel foam, highlighting its potential as a scalable and low-cost alternative for AEMWE.

M-SPIN