

Layered Perovskite Nanofibers with Tailored Entropy for Alkaline Water Electrolysis

Lakshya Mathur, Timileyin Aworinde Aworinde, Wenkai Yang, Shaikh Abdullah Rais Ahmed, Sivaprakash Sengodan, Maryam Tariq Ahmed Khaleel, Lourdes F. Vega

Research & Innovation Center for Graphene and 2D Materials (RIC-2D), Research and Innovation Center on CO₂ and Hydrogen (RICH), Department of Mechanical and Nuclear Engineering, Chemical & Petroleum Engineering Department, Khalifa University of Science and Technology, PO Box 127788, Abu Dhabi, UAE

lakshya.mathur@ku.ac.ae (L. Mathur), sivaprakash.sengodan@ku.ac.ae (S. Sengodan)

Abstract

Achieving net-zero carbon emissions is imperative for mitigating the adverse impacts of climate change, and green hydrogen production has emerged as a cornerstone in this global transition. Central to sustainable hydrogen generation are advanced electrolysis technologies that rely on the development of highly active and stable electrocatalysts. In this study, we investigate the design and synthesis of novel electrocatalysts with enhanced intrinsic activity and increased surface area, focusing on layered double perovskites and medium-entropy alloys for application in the oxygen evolution reaction (OER). Two key materials were developed: an A-site-deficient double perovskite, $\text{PrBa}_{0.5}\text{Ca}_x\text{Co}_{1.5}\text{Fe}_{0.4}\text{Ni}_{0.1}\text{O}_{5+\delta}$ (PBCCFN), and a medium-entropy alloy-based perovskite, $\text{PrBa}_{0.5}\text{Sr}_{0.5}\text{Co}_{1.5}\text{Fe}_{0.37}\text{Ni}_{0.1}\text{Mo}_{0.03}\text{O}_{5+\delta}$ (PBSCFNM). Both electrocatalysts were fabricated into nanofiber architectures via electrospinning, a strategy aimed at increasing the density of active sites by maximizing surface area. Scanning electron microscopy confirmed the formation of continuous, uniform nanofibers, and subsequent calcination at 800 °C for 2 hours preserved their structural integrity. Electrochemical evaluation in a half-cell configuration revealed initial current densities of 9.19 mA cm⁻² for PBCCFN and 4.54 mA cm⁻² for PBSCFNM. Remarkably, both catalysts exhibited significant performance enhancements upon prolonged operation, attributed to dynamic surface reconstruction involving the leaching and redeposition of an amorphous layer, which generated additional active sites. Post-activation, PBCCFN showed a 24% increase in current density, while PBSCFNM demonstrated an 83% enhancement. To further assess practical applicability, PBSCFNM was integrated as the OER electrocatalyst in a zero-gap alkaline water electrolysis membrane (AWEM) system. Under ambient conditions (20 °C, 1 M KOH), the system achieved a cell voltage of 1.95 V at a current density of 150 mA cm⁻², matching the performance of commercially available Ni/Ni-foam catalysts. These findings underscore the potential of PBSCFNM and related nanostructured perovskite-based materials as cost-effective, high-performance electrocatalysts for next-generation green hydrogen production systems.

Figures

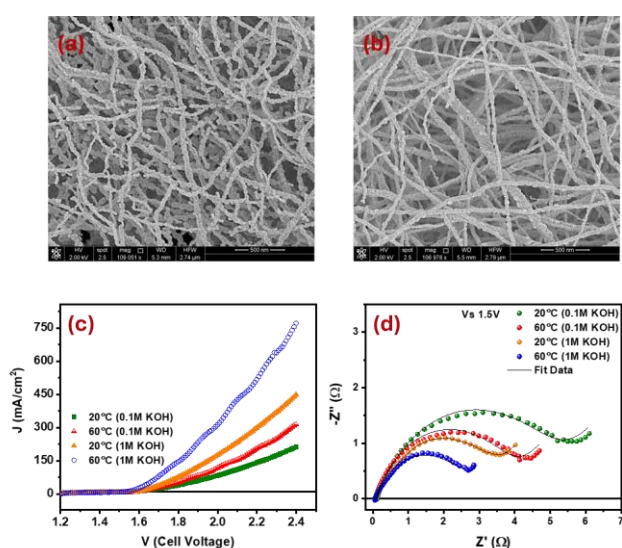


Figure 1: SEM images of calcined nanofibers of (a) PBCCFN and (b) PBSCFNM (c) Linear sweep voltammograms of the fabricated AEM water electrolyzer using a PBSCFNM electrode recorded at varying KOH concentrations; (d) Corresponding Nyquist plots illustrating electrochemical impedance behavior