Proceedings of the 9th International Conference on Energy Harvesting, Storage, and Transfer (EHST 2026)
June, 2026 | Barcelona, Spain
DOI: 10.11159/ehst25.006

Advancing PEM Water Electrolyzers through Integrated Multi-Technique Characterization

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Polymer electrolyte membrane water electrolyzers (PEMWEs) are central to scaling renewable hydrogen production. Advancing these systems requires not only improved materials and components but also a detailed understanding of how fabrication choices and operating conditions influence performance and degradation. Because PEMWEs span multiple length scales and involve complex interactions between components, advancing these systems requires integrated, multi-technique characterization.

This talk will highlight our recent work on catalyst layers (CLs), porous transport layers (PTLs), and porous transport electrodes (PTEs), emphasizing how electron-, X-ray-, and ion-based techniques provide complementary insights into surfaces and interfaces. We first demonstrate how quantitative parameters extracted from scanning electron microscopy – energy dispersive X-ray spectroscopy (SEM–EDS) enable systematic evaluation of CL quality across various CL fabrication conditions. X-ray photoelectron spectroscopy (XPS) offers information on catalyst composition, evolution, and subtle variations at the catalyst–ionomer interface, though challenges remain in assigning specific chemical species. To address these uncertainties, we incorporate time of flight – secondary ion mass spectrometry (ToF-SIMS), which supplies complementary surface, subsurface, and bulk information and strengthens interpretation of XPS results. Given the large parameter space associated with CL properties, we apply principal component analysis (PCA) to identify key correlations among various parameters extracted from multiple techniques and electrochemical performance, offering guidance for the design of more robust oxygen evolution catalysts and provides new perspectives on degradation mechanisms under realistic conditions. Together, these approaches illustrate how coordinated characterization can accelerate the development of durable and efficient PEMWE components.