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Nanocomposite Membranes for Next-Generation Fuel Cells and Electrolyzers

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Abstract

Polymer electrolyte membranes play a crucial role in the efficiency, performance, and durability of electrochemical energy conversion technologies, particularly fuel cells and water electrolyzers. Among the strategies explored to overcome the limitations of conventional membranes, the development of nanocomposite polymer electrolytes has emerged as a promising approach to enhance ionic conductivity, water management, mechanical stability, and long-term durability.

This keynote will highlight recent advances in the design and development of nanocomposite proton exchange membranes (PEMs) and anion exchange membranes (AEMs), focusing on the incorporation of functional nanostructured materials into polymer matrices to tailor membrane properties. Particular attention will be devoted to the relationships between membrane nanostructure, molecular dynamics, and ion transport mechanisms. In this context, Nuclear Magnetic Resonance (NMR) techniques, including pulsed-field gradient (PFG) and relaxation time measurements, provide valuable insights into water dynamics and ion transport within the polymer electrolyte.

By combining innovative materials design with a deeper understanding of structure–property relationships, nanocomposite membranes offer promising opportunities to overcome current limitations in fuel cell and water electrolysis technologies, contributing to the development of more efficient, durable, and sustainable hydrogen energy systems.

Keywords: *Nanocomposite membranes; Proton exchange membranes; Anion exchange membranes; Fuel cells; Water electrolysis; NMR spectroscopy.*

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