SULFONATED NANOCOMPOSITE MEMBRANES

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Proton conductive polymer membranes are widely studied because of their potential use in electrochemical and energy-related applications. Among them, organic–inorganic membranes attract particular interest, as their structure and transport properties can be effectively adjusted by combining polymer matrices with inorganic components.

Optimal membrane compositions were selected based on kinetic analysis using the Alfrey–Price equation. Polymer matrices were prepared by UV-initiated free-radical copolymerization of acrylonitrile, acrylic acid, and sulfonated monomers (SSNa or SPAK), while the inorganic component was introduced simultaneously via in situ sol–gel formation from TEOS and MAPTMS. This integrated synthetic approach resulted in a uniformly distributed, self-crosslinked silica network embedded within the polymer matrix, ensuring effective coupling of the organic and inorganic phases.

The obtained membranes are homogeneous, transparent, and insoluble in water and organic solvents, indicating high chemical stability. SEM analysis revealed a dense, crack-free cross-sectional morphology (Fig 1.). The formation of the designed organic–inorganic structure was further confirmed by EDX and FTIR spectroscopy, which verified the presence of sulfonic acid groups and characteristic bands of the silica phase. The coexistence of these functional components facilitates the formation of hydrogen-bonded networks that support efficient proton transport.

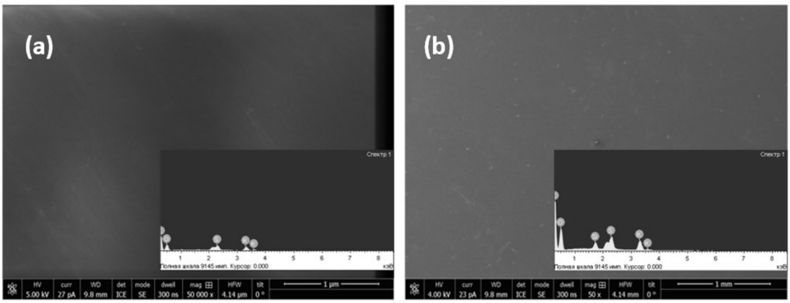

Fig. 1. SEM images and EDX spectra: (a) SPAK; (b) SPAK-SG

Incorporation of the sol–gel-derived silica network enhanced proton conductivity, reaching 7.52 mS cm^{-1} for SSNa-based and 9.8 mS cm^{-1} for SPAK-based membranes at room temperature, while maintaining low methanol uptake (8.8 wt % for SPAK). The integrated organic–inorganic structure improved dimensional stability and enabled efficient proton transport via a Grotthuss mechanism within hydrated ionic domains.

Overall, sulfonated nanocomposite membranes with a well-defined silica network demonstrate high proton conductivity, structural integrity, and limited alcohol permeability, highlighting that controlled organic–inorganic architecture is crucial for designing stable and efficient proton conductive membranes suitable for electrochemical applications.

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