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Creation of Organic-Inorganic Hybrid Ion-Exchange Membranes Based on Inorganic Nanofiber Framework

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Summary

To improve the performance of ion-exchange membranes (IEMs), particularly to reduce the electrical resistance of IEMs, the formation of thinner membranes is one promising approach. For the conventional IEMs used for producing sodium chloride by electrodialytic concentration of seawater, the thick woven fabrics have been used as a reinforcement. Recently, IEMs based on porous polymer thin films as a reinforcement have attracted much attention particularly for battery applications. On the other hand, ultrathin fibers, called "nanofibers" are a unique nanomaterial based on the intrinsically size-dependent functions such as large surface-to-volume ratios and high molecular orientation or confined polymer chains inside the fibers. Nanofiber nonwovens sheets with random network structure have high porosity (> 90%) and interconnected pore structure. It has been reported that the three-dimensional nanofiber networks can be utilized as high-performance filter media and also mechanically reinforce the polymer matrix in the composites.

In this work, organic-inorganic hybrid IEMs based on inorganic nanofiber framework were prepared and characterized. Porous silica nanofiber sheets (porosity > 94%) were prepared by electrospinning and successive calcination and used as a porous reinforcement. Cation-exchange membranes, composed of poly(styrene-*co*-divinylbenzene) containing sulfonic acid groups, and anion-exchange membranes, composed of poly(4-vinylpyridine-*co*-divinylbenzene) containing quaternary pyridinium groups, were prepared by radical copolymerization and post treatment after the impregnation of the monomer solutions into the silica nanofiber sheets. Compared to the conventional porous polymer films, the prepared porous silica nanofiber sheets substantially increased the ion-exchange-component ratio in the membranes. Consequently, the ion-exchange capacity increased and electrical resistance decreased, in particular for the cation-exchange membranes.