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Preparation of Nano-Structure Controlled Ion-Exchange Membranes by Ion Beams and Their Application to Seawater Concentration II

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Summary

Ion-exchange electrodialysis membranes with low electrical resistance and high permselectivity have been required for applications to a seawater concentration process. The present study deals with the preparation of nano-structure-controlled cation- and anion-exchange membranes (CEMs and AEMs) by a so-called ion-track grafting technique. This new technique involves irradiation of a polymer substrate with an MeV-GeV heavy-ion beam and the graft polymerization into the resulting latent tracks. If the ion-exchange groups are introduced only into the nano-sized cylindrical tracks, the surrounding substrate matrix without any modifications is expected to mechanically prevent any excess swelling, thereby improving the ion transport properties.

A 25-mm-thick poly(ethylene-*co*-tetrafluoroethylene) (ETFE) film was irradiated with 560 MeV ^{129}Xe or 310 MeV ^{84}Kr ion beam. The irradiated ETFE films were immersed in grafting solutions of ethyl *p*-styrenesulfonate (EtSS) and chloromethyl styrene (CMS) and then afforded to hydrolysis and quaternization of the grafted chains for the preparation of CEMs and AEMs, respectively. Not only the EtSS and CMS grafting reactions but also the following hydrolysis and quaternization proceeded quantitatively, resulting in the preparation of the CEMs and AEMs with widely-controlled ion exchange capacities.

The resulting CEMs and AEMs possessed ion transport properties exceeding those of commecially-available products, that is, a membrane resistance of $< 2.0\ \Omega\ cm^2$ and transport number of > 0.98. Microscopic structural analyses demonstrated that the latent tracks of the two different ions enabled us to control the diameter of cylindrical charged channels extending perpendicularly to the membrane thickness. An electrodialyzer with a pair of our CEM and a commercially-available AEM or vice versa exhibited a higher concentration of chloride in the concentration chamber than a pair of the commercially-available CEM and AEM, where 0.5 mol/L NaCl aqueous solution was used as a seawater model.