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

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Summary

Until recently, many researchers have been developing better ion-exchange electrodialysis membranes 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 a 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 ion transport properties.

A 25-μm-thick poly (ethylene-*co*-tetrafluoroethylene) (ETFE) film was irradiated with a 560 MeV ^{129}Xe 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 controlled ion exchange capacities up to 2.0-2.5 mmol/g.

The water uptake and resistance were lower for our ion-track grafted CEMs and AEMs than for the conventional γ-ray-grafted membranes, and strikingly the transport number was also comparable to that of a commercially-available membrane. This would be because local and high-density energy deposition due to the ion beam enabled us to control the membrane structure in a nanometer scale. The track diameter was theoretically estimated to be ca. 250 nm, and the volume percentage of the tracks was only 14% at a fluence of 3.0×10^{8} ions/cm^2. A key for success here is to achieve high graft levels in as small a number of tracks as possible.