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Can the electrochemical performance of heterogeneous ion-exchange membranes be better than that of homogeneous membranes?

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Abstract

Competition between homogeneous and heterogeneous ion-exchange membranes (IEMs) lasts for decades. Low fraction of conductive surface area, Θ, of IEMs causes lower limiting current density, higher voltage and water splitting rate at a same average current density. On the other hand, heterogeneous IEMs are less costly. Additionally, as it was found recently, electrically heterogeneous surface enhances electroconvection. In this paper, we consider a heterogeneous anion-exchange MA-41 membrane (Shchekinoazot) and two its modifications. The first one (MA-41P) is prepared in the same way as the MA-41 membrane and contains the same resin particles, but of a larger size; these larger particles are rearranged on the surface to form agglomerates separated by non-conductive regions. The value of Θ for the MA-41P membrane is 1.5 times greater than that for the MA-41 and the height of "hills" formed by the resin particles on the surface is 3 times higher. The second membrane (MA-41PM) is obtained from the MA-41P by treatment of its surface with a bifunctional polymer solution allowing transforming the functional tertiary and secondary amino groups into the quaternary ones, Θ remains the same. We compare the main physico-chemical (ion-exchange capacity, water content), surface (SEM-EDS analysis, optical microscopy, contact angle) and electrochemical (pH-metry, voltammetry, chronopotentiometry, impedancemetry, water splitting and mass transfer rate) properties of the three mentioned above membranes with those of a homogeneous Neosepta AMX membrane (Astom), in a 0.02 M NaCl solution. The experiments show that the water splitting rate decreases in the sequence MA-41>MA-41P>AMX≥MA-41PM. For the membranes in this sequence above the experimental limiting current densities normalized at the theoretical limiting current density are 0.6, 0.8, 1.3 and 1.25, respectively. However, the voltage at a same overlimiting current density is still greater across the MA-41PM than across the AMX membrane.