ELECTROOSMODIALYSIS

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Concentration Polarization (CP) and limiting-current phenomena are well-known to limit the productivity of electrodialysis by reducing the current efficiency at higher current densities. Considerable effort has been devoted to attempts to reduce the CP primarily via intensification of external mass transfer close to the membrane surfaces. However, it is notoriously difficult to stir liquids very close to solid surfaces so intensification of cross-flow hydrodynamics has only limited impact and obviously implies additional energy costs.

In conventional electro-membrane systems, limiting-current phenomena occur because salt is delivered to polarized membrane/solution interfaces primarily by diffusion. Its rate is limited since the salt concentration cannot drop below zero. In liquids convection is a much more effective transport mechanism than diffusion. Therefore, much attention has been paid to the so-called electro-convection in electro-membrane processes. Nonetheless at short distances from the membrane surfaces even electro-convection remains predominantly tangential so its rate is limited due to the no-slip condition. Normal convection would be much more effective but in the case of conventional ion-exchange membranes it is very week owing to the extremely low mechanical permeability of these membranes. At the same time, with nano-porous charged diaphragms the limiting current can be effectively suppressed due to the normal electro-osmotic flow [1].

This presentation will show in what way considerable (quasi)normal convective flow through ion-exchange membranes (IEXMs) can be arranged for. This can be achieved via creating relatively scarce microscopic perforations in the otherwise almost impermeable membrane matrix. The transmembrane volume flow can be created in several ways but in this presentation we will consider the scenario of putting a nano-porous layer in series with the perforated IEXM so that the former works as an electroosmotic pump. In this case the liquid flow through the perforated IEXM is predominantly driven by the electroosmotic pressure gradients arising within the nanoporous electroosmotic layer. Via numerical simulations, we will demonstrate that due to this (quasi)normal convection (and corresponding salt delivery to the current-polarized interface), limiting current, indeed, is suppressed. Nonetheless, the CP phenomenon itself does not disappear. With increasing current density the salt concentration tends not to zero but to a finite limiting value, which is a function of system parameters. Evidently, in addition to the decrease in the concentration (similar to the conventional ED) there is a volume transfer across the “sandwich”. If a cell pair is formed by two perforated IEXMs of opposite polarity (each “sandwiched” with its own nanoporous EO layer of opposite surface charge) the volume flows through the composite membranes have opposite directions and can merge into a tangential flow along a channel separating them. Due to this, one can expect increased product recovery as compared to the conventional ED. In view of the important role played by electroosmosis, this novel membrane separation process can be termed ElectroOsmoDialysis (EOD).