Multiphysics Simulation of Ion Concentration Polarization Induced By Nanoporous Membranes in Dual Channel Devices

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I. Time-variant pre-concentration results

- EOF transports trace molecules from the high voltage end to the low voltage end in the anodic channel.
- The electrokinetic balance for trace molecules is reached near the ion depletion zone (IDZ) inducing accumulation of trace molecules.
- The qualitative consistency between simulation and experimental results validates our modeling method.

II. Flow Field Distribution Near The Nanoporous Membrane

- Vortex flows and secondary flows (slow-flow zone) are generated near the membrane. The velocity of the vortex ranges from 1 mm/s to 20 mm/s which is much faster than the velocity of EOF (~ 40 mm/s).
- The flow velocity at the channel wall is not zero and varies with time because an electroosmotic-slip boundary condition is applied and the electric field along the channel also varies. Consequently, the flow velocity at the channel wall expresses the strength of local electric fields.
- The profile of flow along A-A’ or B-B’ is not flat as the normal EOF does because the existence of vortex flow enhances the flow rate.

III. The Influence of Electric Potential on Pre-concentration

- The increase of electric potential will enhance the flow field around the membrane.
- The profile of concentrated areas gets smaller when the applied electric field is higher because of a strong effect of diffusion.
- Additional electric potentials can increase the net flux of trace molecules.

IV. The Influence of EPM and Charge Density on ICP

- The results show the influence of different EPMs and charge densities on the results of pre-concentration.
- High EPM of counter-ions in the membrane should be applied to obtain high CEF.
- The results reveal that high EPM of counter-ions in the membrane should be applied to obtain high CEF.

Conclusions

1. We have simulated ICP development and vortex generation in a DC-ICP device with improved boundary conditions and a wide range of EPMs.
2. We validated the 2-D model and simulation results with experimental ones in terms of CEFs, ion concentrations, electric fields, and flow fields under various electric potentials.
3. It was demonstrated that pre-concentration is significantly affected by electric potentials and flow fields including vortex flows and a slow-flow zone induced near the nanoporous membrane.
4. We found that the EPMs of counter-ions in the nanoporous membrane play key roles in ICP phenomena.

References


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