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PROCEEDINGS

Direct Numerical Simulation of Electroconvection near an Ion-Selective Membrane Under Magnetic Field

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ABSTRACT

We study the effect of magnetic field on the electro-hydrodynamics of ion transport in a liquid electrolyte near an ion-selective membrane using direct numerical simulation. Ion transport across the ion selective membrane plays an essential role in many electro-hydrodynamic and electro-microfluidic systems. Above a critical voltage, electroconvective instability occurs near the membrane surface, causing vortical flows in liquid electrolyte which enhances the mixing of cations and anions, increases the ion transport efficiency and causes current fluctuations. When the system is under a magnetic field, the Lorentz force generated by the ion movement can significantly change the flow of electrolyte solution. This effect has been used to stir fluids in microfluidic devices or to suppress the electroconvection when combined with the electric field. We add the Lorentz force in the coupled Poisson-Nernst-Planck-Stokes equation and study the effects of magnetic field on a two-dimensional electroconvection field. Simulation results show that when the magnetic field is applied perpendicular to the flow, the Lorentz force drives a net cross-flow similar to a Poiseuille flow across the two ion-selective membranes. At a high Hartman number, the electroconvection instability is fully suppressed when the applied voltage is slightly above the critical voltage. This effect essentially has the same physical mechanism as the pressure-driven channel suppressing the electroconvection. However, at a high Peclet number, the strong electroconvection cannot be fully suppressed and the cross flow is stronger than the corresponding Poiseuille flow driven by a body force which has the same average magnitude of the Lorentz force. Furthermore, we quantify the relative importance of energy dissipation due to viscous effects and magnetic effects in various transport regimes. Our results show that the external magnetic field has the strongest effect in the space charge layer regime.

KEYWORDS

Electroconvection; magnetohydrodynamic

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