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PARTICLE IMAGE VELOCIMETRY METHOD FOR TRACING VORTICES ON ION-EXCHANGE SYSTEMS

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Abstract: Electrodialysis and electrodeionization are membrane separation processes used industrially to purify water and separate ionic components from processed solutions. These processes are based on the use of a system of membranes which provide selective transport of ionic species contained in the electrolyte while in electric field. Besides the knowledge of selectivity and permeability of the membranes, it is also important to study the behavior of liquid flow on both sides of the membranes especially in case when the flow is caused by the electric field. This motion of fluid is called electroconvection. One of the most employed engineering methods to track the liquid motion is Particle image velocimetry (PIV). This method helps to experimentally analyze flows in various engineering systems, such as flows in pipes or aerodynamics study in automotive and aviation industry. In our experiments, we use Particle Image Velocimetry to qualitatively analyze the liquid flow in the electrolyte adjacent to the membrane under study.

Specifically, we exploit PIV to trace liquid flow around ion-exchange systems integrated in micro-fluidic systems with the focus on the depleted side while an external electric field is applied. Ion-exchange membranes bear three-region current-voltage characteristics typical for ion selective systems (under-limiting, limiting and over-limiting). The electroconvection is characteristic for the over-limiting region. After exceeding the limiting current, the system becomes hydrodynamically unstable which leads to formation of strong vortices in the electrolyte layer on the depleted side of the membrane.

By using PIV, we are able to qualitatively characterize the liquid flow, i. e. to reconstruct the velocity field and determine the direction or direction of rotation of the formed vortex or vortex array. On quantitative analysis, we are also able to determine local liquid flow rate of a thin layer of electrolyte which is in focus of our camera during the measurement. In this work, we focus on: (i) finding the optimal measuring conditions to obtain accurate and reproducible PIV results, (ii) finding the dependence of the local flow rate on the concentration of KCl, (iii) reconstructing a profile of the liquid flow on the depleted side of the membrane, and (iv) characterizing rotating vortices.