MRI velocimetry of dynamics based on the Lorentzian force in electrochemical cells

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Electrochemical reactions are a crucial part of modern technologies such as batteries or fuel cells. NMR and more specifically MRI has evolved to a powerful tool to gain deeper insights into these processes. A problem arising with this methodology is the influence of the magnetic field on the process itself. Since an electrochemical cell features moving ions and therefore moving charges, a magnetic field will cause Lorentz forces, also known as the magnetoelectrolysis effect[1]. The force on the ions also effects the solvent (hull) and therefore results in significant flow within the cells. Depending on the orientation of the electrodes with respect to the magnetic field direction, different flow patterns can be observed. This motion inherently effects measurements of electrochemical cells and therefore characterization of the flow field is crucial.

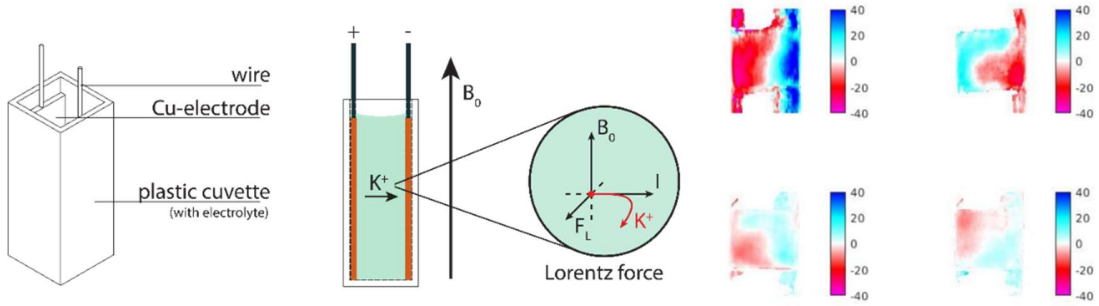

Figure 1. Left: Design of the electrochemical cell and observable effect. Right: Out of plane velocities (mm/s) of a cuvette filled with salt water at different currents measured utilizing FLIESSEN. The electrodes are attached to the cuvette walls (top/bottom in the images). Top row: +/- 20 mA; Bottom row: +/- 5 mA.

This study uses phase-contrast velocimetry (FLIESSEN[2], spin echo velocity imaging) to analyse these flow-patterns under in-situ conditions. The cell design was deducted from Britton et al[3]. The electrodes were carefully aligned with the $\boldsymbol{B}_1$-field orientation. The measurements clearly show fluid motion within the cell. On small timescales vortices can be observed (Figure 2). Different currents as well as reactions were tested. Furthermore, the measured flow-maps are compared to videos of the effect outside of the measurement field.

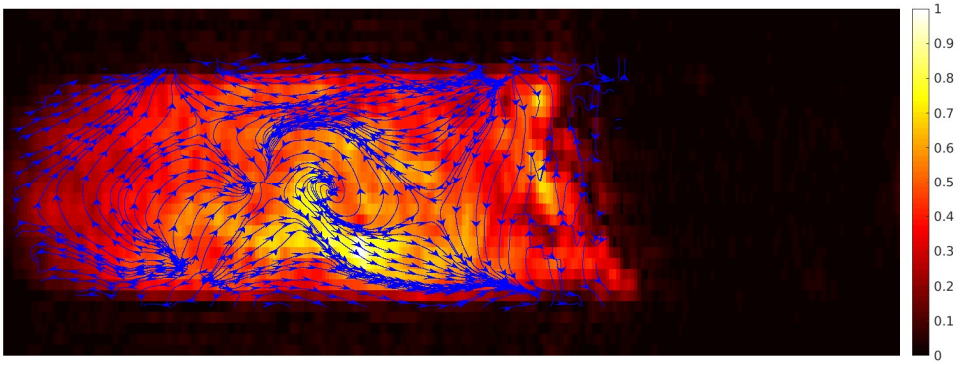

Figure 2. Streamline plot of a cuvette cell filled with a 1M $CuSO_4$ solution measured with spin echo velocity imaging. The plane is parallel to the electrode plates. In the background, the spin density is depicted.

Bruna F. Gomes acknowledges support from Grants FAPESP 2012/22281-9 and 2016/01537-6.

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[3] J. M. Bray, A. J. Davenport, K. S Ryder, M. M. Britton, Angew. Chem. Int. Ed. 55 (2016) 9394-9397.