Why Multi-Physics Flow Problems Are Different — Challenges in the Simulation of Electro-Dialysis

A. Linke[1] and V. John[1,2]

[1]Department of Mathematics and Computer Science, Free University Berlin, Arnimallee 6, 14195 Berlin, Germany, alexander.linke@wias-berlin.de

[2]Weierstrass Institute, Mohrenstr. 39, 10117 Berlin, Germany, volker.john@wias-berlin.de

Coupled multi-physics flow problems remain to be a challenge for numerical simulations. Indeed, recent research[1] has shown that in multi-physics problems even the simulation of supposedly simple flows – like Stokes flows – can be a difficult task. A physical reason for this is that many coupled flows of practical interest act in a physical regime that is different to the standard example of *flow in a pipe around an obstacle* — a regime where present-day flow solvers, e.g. based on mixed finite elements, work pretty well. In the talk, we will demonstrate these general considerations presenting an application from electro-dialysis[2] that can be modelled by the Nernst-Planck-Poisson-Stokes problem. Here, strong electro-static forces are applied to an electrolyte, in order to separate positive and negative ions. We argue in the talk for the development of appropriate *compatible discretizations*[3] for the Nernst-Planck-Poisson-Stokes system — especially for the development of exactly divergence-free flow solvers, in order to handle large conservative forces properly. Such a divergence-free flow solver is expected to be the missing link between the ion-transport part of the problem — for many years investigated at the Weierstrass Institute in the context of semiconductor device simulation[4, 5] — and the actual fluid flow part.

References

[1] K. Galvin, A. Linke, L. Rebholz, N. Wilson, *Stabilizing poor mass conservation in incompressible flow problems with large irrotational forcing and application to thermal convection*. CMAME, accepted, 2012.

[2] B. Zaltzman, I. Rubinstein, *Electro-osmotic slip and electroconvective instability*. Journal of Fluid Mechanics, 2007.

[3] D. Arnold, P. Bochev, R. Lehoucq, R. Nicolaides, M. Shashkov, *Compatible Spatial Discretizations*. Springer, New York, 2006.

[4] K. Gärtner, A. Glitzky, *Energy estimates for continuous and discretized electro-reaction-diffusion systems*. Nonlinear Anal., 2009.

[5] K. Gärtner, *DEPFET sensors, a test case to study 3D effects*. J. Comput. Electron., 2007.