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Microfluidic systems for separation and preconcentration of ion species using the ion depleted zone

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Microfluidics represents a rapidly developing area of research with applications in modern analytical chemistry and bioengineering. One phenomenon that can be utilized in such systems is ion concentration polarization (ICP), which occurs when an electric potential is applied to a system containing ion-selective membranes. The selective transport of ions across these membranes due to an electric potential difference leads to the formation of two characteristic regions. In one region ions accumulate, forming the so-called ion-enriched zone, while in the other region, referred to as the ion-depleted zone, the ion concentration is significantly lower than in the bulk solution.

In this work we focus on the ICP phenomenon utilized for the separation and preconcentration of various ions based on their charge number. As part of our research, we developed and analyzed a mathematical model of ICP, which requires solving a complex system of partial differential equations, namely the Navier–Stokes, Nernst–Planck, and Poisson equations. Numerical simulations were performed using COMSOL Multiphysics, allowing us to describe the ICP phenomenon in detail and to conduct several parametric studies of the system.

The developed model was subsequently compared with experimental data obtained using a microfluidic device of our own making. These experiments demonstrated that such a device is capable of separating different dyes based on their electrophoretic mobility, thereby giving us another alternative for ion separation in microfluidic devices.