ABSTRACT

Modern Ion Exchange experiments - From Charge Attachment induced Transport (CAIT) to Alkali Proton Substitution (APS)

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Ion exchange experiments find broad application in science and technology. They form the basis for, e.g., ion-exchange chromatography (analytical chemistry) and glass hardening (material science). Conventional applications operate on the basis of chemical concentration gradients as the driving force and are thus inherently bi-directional. In contrast to that electric field driven ion exchange experiment can and in general will induce uni-directional ion transport.

The goal of this contribution is to highlight current efforts in advancing techniques for electric field driven ion transport and to discuss possible applications. In this context, the focus will be on two techniques, i.) the charge attachment induced transport (CAIT) technique and the alkali proton substitution (APS).

The CAIT technique has been developed in the authors group. It is based on shining a charge carrier beam (ions or electrons) at the surface of a sample, which is in contact with a single metal electrode on the backside. Charge carrier attachment induces uni-directional transport in the sample [1],[2],[3],[4],[5]. The APS technique has been developed in Omata's group. It is based on converting molecular hydrogen to protons at the interface between a Pt electrode and a sample. The electric field applied drives unidirectional transport of ions through the sample [6],[7],[8].

Intellectual understanding of the ion exchange is achieved by analyzing concentration depth profiles by means of secondary ion mass spectrometry (SIMS) and modelling those profiles by the Nernst-Planck-Poisson (NPP) theory. For selected examples SIMS profiles are complemented by hardness measurements (Cynthia Volkert, Göttingen) and nuclear reaction analysis data (Udo v. Toussaint, München)

References

[1] K.-M. Weitzel, Current Opinion in Electrochemistry 2021, 26, 100672.
[2] M. Schäfer, K.-M. Weitzel, Mater. Today Phys. 2018, 5, 12.
[3] M. Schäfer, D. Budina, K.-M. Weitzel, PCCP 2019, 21, 26251.
[4] J. L. Wiemer, M. Schäfer, K.-M. Weitzel, J. Phys. Chem. C 2021, 125, 4977.
[5] V. H. Gunawan, M. Schäfer, K.-M. Weitzel, PCCP 2024, 26, 14430.
[6] T. Ishiyama, S. Suzuki, J. Nishii, T. Yamashita, H. Kawazoe, T. Omata, J. Electrochem. Soc. 2013, 160, E143-E147.
[7] T. Ishiyama, J. Nishii, T. Yamashita, H. Kawazoe, T. Omata, J. Mater. Chem. A 2014, 2, 3940.
[8] K. Rein, K.-M. Weitzel, J. Mater. Chem. A 2024, 12, 14117.