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High-temperature polymer electrolyte fuel cells based on protic ionic liquids

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Polymer electrolyte membrane fuel cells (PEMFCs) are considered as efficient converters of chemical energy stored as hydrogen into electrical energy. Increasing their operation temperature to 100–160 °C would allow for a simpler water management and the use of waste heat. In this way, the overall system costs could be reduced promising a widespread application of PEMFCs in the mobility sector, in particular for heavy duty vehicles. Conventional PEMFCs, which are already commercially available nowadays, employ NAFION® as a membrane material, whose proton conductivity relies on the presence of liquid water. Hence, alternative membrane materials need to be developed for high-temperature application.

In this contribution, a study on protic ionic liquids (PIL) as electrolytes, immobilized in polybenzimidazole (PBI) membranes, is presented. PILs are particularly suited for fuel cell applications as they provide a high thermal and chemical stability and a high proton conductivity [1]. We performed experimental investigations and atomistic simulations of the electric double layer formed between an ionic liquid and a Pt electrode. Our results reveal that the electrode-electrolyte interface consists of densely packed alternating anion and cation layers and thus behaves fundamentally different from that of aqueous solutions [2]. As the fuel cell performance is determined by the electrochemical reactions at the interface, we particularly focus on the influence of the acidity of the ionic liquid on the oxygen reduction reaction (ORR).

We perform solution casting of PBI membranes doped with ionic liquids and investigate the interactions of the electrolyte with the host polymer. Microscopic analysis reveals that a porous polymer structure can be formed, which allows for an encapsulation of the ionic liquid within the pores [3]. Using slight doping with phosphoric acid, the polymer walls surrounding the ionic liquid-filled pores can be made conductive and the doped membranes showed a satisfactory fuel cell performance in a proof-of-principle cell test.

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2. Rodenbücher, C.; Chen, Y.; Wippermann, K.; Kowalski, P.M.; Giesen, M.; Mayer, D.; Hausen, F.; Korte, C. The Structure of the Electric Double Layer of the Protic Ionic Liquid [Dema][TfO] Analyzed by Atomic Force Spectroscopy. *Int. J. Mol. Sci.* **2021**, *22*, 12653, doi:10.3390/ijms222312653.
3. Skorikova, G.; Rauber, D.; Aili, D.; Martin, S.; Li, Q.; Henkensmeier, D.; Hempelmann, R. Protic Ionic Liquids Immobilized in Phosphoric Acid-Doped Polybenzimidazole Matrix Enable Polymer Electrolyte Fuel Cell Operation at 200 °C. *J. Membr. Sci.* **2020**, *608*, 118188, doi:10.1016/j.memsci.2020.118188.

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