

Ion-selective desalination materials

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Water scarcity is a global problem that is anticipated to get more critical in the future years if no action is taken. According to the World Health Organization report, in 2020, two billion people still did not have access to safely managed clean water services¹. Freshwater makes up only 2.5 percent of global water distribution, and most of it is stored as glacial water or deep groundwater. Because of the high salt concentration, earth-abundant sea- and brackish water cannot be utilized directly as household water.

Desalination technology is a powerful way to lower salt concentration. It has been used to help alleviate freshwater shortages in water-scarce locations, including Africa, Asia, and the Middle East. One promising candidate to be on par with sustainability requirements is Capacitive Deionization (CDI) technology. The best CDI electrode materials require a large specific surface area, suitable pore size, hierarchical porous structure, high hydrophilicity, and high electrical conductivity². This work aims to improve the conventional CDI systems by introducing the ion intercalation materials³ to accumulate Na⁺ and Cl⁻ ions in the bulk of the sodium storage and chloride storage electrodes. The outcome is to provide a material with the synergistic combination of ion removal processes not only through the adsorption in the electrical double layer of the porous electrodes as in the case of classical CDI but also to add high capacity for salt removal by introducing ion intercalation materials.

For this purpose, Cu-substituted, Ni- and Co-doped analogs of Prussian blue were synthesized.

The electrochemical properties of the obtained materials were studied using cyclic voltammetry in a three-electrode system in 0.1 M NaClO₄, 0.1 M KClO₄, and 0.1 M LiClO₄ aqueous solutions, focusing on the cation intercalation. The results confirmed that these Prussian Blue analogs work selectively for Na⁺ cations. K⁺ cations deviate from the optimal behavior, and Li⁺ cations cannot wholly penetrate the ion channels. It arises from the mismatch between the size of the ion channels and hydrated Li⁺ ions (3.2 Å vs. 3.82 Å). Due to the high charge density and the strong electrostatic interaction of the solvate shell of the Li⁺ ion, it cannot be completely removed⁴. Ni-doped Prussian blue analog material also expressed the highest activity towards Na⁺ ion intercalation, making it suitable choice for combining with carbons with large specific surface area, appropriate pore size, and hierarchical porous structure⁵⁻⁷ for hybrid CDI applications.

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