Multiple Ion Removal with Fast and Charge-Efficient Desalination of Asymmetric Capacitive Deionization by Hydrated Intercalation

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Capacitive deionization (CDI) that engages porous carbon electrodes is one of the well-established energy-efficient desalination techniques. However, the desalination performance is still desired to improve further for a wide range of applications. Herein, an asymmetric CDI is introduced by pairing Prussian blue analogue (PBA) and porous carbon electrodes. The exclusive intercalation of cations into the PBA prevents the reverse adsorption, thus significantly improving ion removal capacity and charge efficiency. Besides, since diverse cations can be intercalated into the A sites of the PBA at similar redox potentials, the asymmetric CDI can treat multiple cations at once during desalination without selectivity for specific valence. Moreover, cations are intercalated in the hydrated forms without a discrete phase transition of the host structure, facilitating fast desalination by reducing the desolvation energy penalty at the electrode-water interface. This study offers a new design principle in CDI, that is, the integration of a crystal structure with large ionic channels that enable the hydrated intercalation of multiple ions in a fast and exclusive manner.