Department of Materials Science and Engineering,

MS Defense

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Hybrid Capacitive Deionization of Mixed and Single Ion Solutions using 1D and 2D Advanced Functional Materials

Michael Barsoum
Ekaterina Pomerantseva

Abstract:

As global temperatures rise & water consumption increases, freshwater is becoming a scarce commodity. Selective removal of ions is a burgeoning area of research for ion harvesting & water infrastructure, but traditional desalination techniques are not capable of selective removal. In this work, hybrid capacitive deionization is presented as a low energy, efficient solution to the water crisis using one-dimensional (1D) & two-dimensional (2D) advanced intercalation compounds that are studied for selectivity. 1D tunnel manganese oxide (TuMO) nanowires displaying a highly controllable rectangular tunnel size, which can be used for ion removal, are synthesized, formulated into electrodes, and studied in single-ion and multi-ion solutions for the first time. It is observed that in single-ion solutions, smaller tunnels prefer ions with a smaller size. In mixed solutions, however, the charge of the ions plays a more critical role. TuMO electrodes show preference toward removal of the Mg^{2+} & Ca^{2+} ions, which is attributed to higher mobility of doubly charged ions in water. The removal of singly charged Li^{+} & K^{+} ions is suppressed in the mixed solutions, which is likely caused by a charge screening mechanism. Finally, binderless 2D MXene electrodes are implemented without traditional current collector materials, as MXene itself acts as the current collector. MXene electrodes are studied in NaCl solutions, and a salt adsorption capacity of 39.1 mg g^{-1} of NaCl is reported for bi-stacked electrodes. This research sheds light on the ion dynamics between redox active electrode materials & ionic species in mixed solutions & has far reaching impacts for the next generation of HCDI for selective ion removal.