

Ion transport within two-dimensional nanofluidic channels

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As the ever-increasing energy consumption and demand raise concerns about energy security and sustainability, advancing energy storage and conversion technologies has become crucial. This challenge necessitates not only enhancing the safety of existing energy storage devices but also developing renewable energy conversion systems and improving their efficiency, such as osmotic energy. Two-dimensional (2D) nanofluidic membranes enable the manipulation of confined ion transport within sub-nanometer interlayer space with exotic and promising properties such as ultrafast ion transport and precise ion selectivity, playing a crucial role in these advanced developments[1, 2]. For example, our group has found that abundant metal vacancies in transition-metal phosphorus trichalcogenides not only serve as proton donor centers but also facilitate proton desorption, leading to ultrahigh proton conductivity in this class of nanofluidic membranes[3]. Additionally, we observed that exfoliating layered materials to the monolayer limit significantly reduces the interactions between protons and the layer frameworks, which provides another effective strategy to enhance proton conductivity, as demonstrated in $\text{H}_3\text{Sb}_3\text{P}_2\text{O}_{14}$ and HSbP_2O_8 membranes[4]. This talk will focus on the design and regulation of physical/chemical properties of the 2D nanofluidic channels to overcome limitations in ion conductivity and selectivity, thereby achieving higher performance in energy-related applications. First, through defect engineering, vacancy-containing CdPS_3 nanosheet-based membranes, intercalated with a high density of diverse cations, exhibit superhigh conductivities (~ 0.01 to 0.8 S cm^{-1}) for both monovalent and multivalent ions across a temperature range of -30 to $90 \text{ }^\circ\text{C}$, demonstrating their potential as versatile superionic conductors[5]. Furthermore, by leveraging surface charge and interlayer spacing through modification of materials charged by functional groups like graphene oxide, as well as developing intrinsically charged layered materials via isomorphous substitution such as cationic and anionic clays, remarkable cation/anion selectivity can be achieved, which contributes to efficient ion separation and osmotic energy conversion[6, 7].

References

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