Engineering Stable Nanochannels in MoS_2 Membranes for Water Purification

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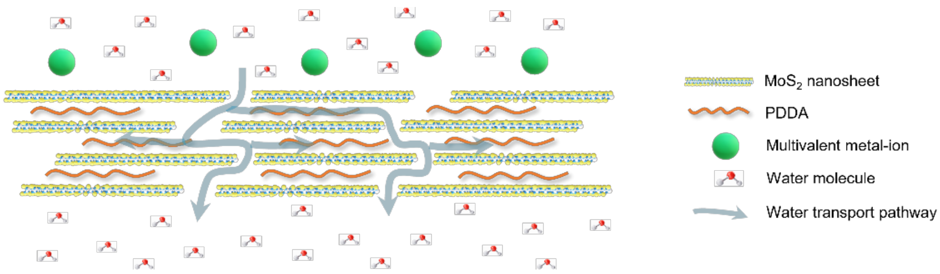
Abstract:

Fresh water scarcity has stimulated the development of advanced membranes for water purification. Two-dimensional (2D) materials can be used as building blocks to prepare lamellar membranes with 2D nanochannels for selective mass transport. However, most of 2D membranes such as graphene oxide (GO) membranes have unstable microstructure, rendering it unfeasible to be employed under realistic conditions such as cross-flow operation. Moreover, the pristine channels of most 2D membranes are negatively charged, undesirable for the separation of multivalent metal ions. In our work, we show that aqueous-stable MoS_2 membranes with positively-charged nanochannels can be prepared by introducing polycations during the stacking of MoS_2 nanosheets. Linear poly(diallyldimethylammonium chloride) (PDDA) with flexible backbone is confined to the 2D channels of MoS_2 membranes, acting as spacers to enlarge the channel width. Upon PDDA intercalation at an appropriate amount (12.0 wt.%), the channel size of MoS_2 membranes increases from 2.8 to 7.7 Å, enabling effective size exclusion for water/salt selectivity. In addition, the intercalated PDDA imparts substantial positive charges to the nanochannels, which are favourable to the repulsion of multivalent cations due to electrostatic repulsion. More importantly, the PDDA-intercalated MoS_2 membrane exhibits superior structural stability, with an almost unchanged channel size after immersion in water for over 60 days. This structural stability can be ascribed to the interlocking effect enabled by the electrostatic attraction between electron-rich 1T-MoS_2 nanosheets and quaternary amine groups in PDDA. Benefiting from the above properties, the developed MoS_2 membrane shows excellent separation performance towards multivalent metal ions including Mg^{2+}, Cr^{3+}, Mn^{2+}, Ni^{2+}, Co^{2+}, and Cu^{2+}, as well as operation stability under harsh cross-flow conditions. Our strategy for engineering stable and positively-charged nanochannels in MoS_2 membranes offers opportunities for the development of advanced 2D membranes for water purification.



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