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Plasma-Treated Nanoporous Graphene Oxide Membranes For Molecular Separation

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Abstract: Graphene oxide (GO) membranes provide a versatile platform for molecular separation due to their layered structure and tunable transport channels. In this study, nanoporous GO flakes with high sp^2 carbon domain density were synthesized via 60-second microwave-assisted annealing, generating in-plane pores that enhance diffusive transport. These flakes were intercalated with MXene sheets, followed by plasma treatment to induce rapid self-crosslinking, resulting in stable, physically crosslinked nanolayers with suppressed interlayer swelling. The membrane's architecture promotes selective transport through nanoconfined pathways where molecular diffusion and electrostatic exclusion govern separation. Water permeance reached 3.6 LMH/bar under low-pressure operation, reflecting low hydraulic resistance and high pore connectivity. The membrane exhibited strong ion sieving behavior, with >90% rejection for NaCl and $MgCl_2$ at concentrations ranging from 500–1000 ppm. This performance results from hindered ion diffusion due to narrow interlayer spacing and Donnan exclusion effects, particularly for multivalent ions.
Additionally, the membranes achieved complete (100%) rejection of various dye molecules, indicating effective size-exclusion-based diffusive barriers. The coupling between membrane structure and mass transfer resistance enables performance beyond conventional polymeric membranes. Plasma-assisted crosslinking enhanced mechanical integrity and preserved selective transport under prolonged operation.
Overall, this study demonstrates how nanoscale design and interfacial control using microwave annealing and plasma treatment can tailor transport properties in GO–MXene membranes, providing a robust strategy for high-performance molecular separations.