Scalable production of graphene membranes with narrow atomic pores by chemical activation

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Graphene with atomic pores < 1 nm in size can be an ideal membrane because of their two-dimensional atomic-scale layer, low biofouling tendencies, chemical resistance, mechanical durability, high selectivity, and fast molecular transport across the membrane. Although atomic pores in bulk-scale graphene is essential to realizing the mass production of high-performance graphene membranes, current studies on graphene membranes rely on low-scale production of graphene with mesopore or nanopore structures and graphene oxide. In this study, we found that simple potassium hydroxide activation can generate precise atomic vacancy defects (~5 Å) in bulk scale graphene while maintaining a two-dimensional sp^2 carbon bonded structure. Permeation tests show very fast permeation of H_2 gas through the graphene membrane with atomic vacancy defects on its basal plane even at low differential pressure (5 kPa), but CH_4 (< 13 kPa), N_2 (< 24 kPa) and CO_2 (< 37 kPa) cannot permeate the membrane. Additionally, prepared graphene membranes with atomic pores were used for desalination, showing the high rejection of NaCl. We believe that our approach will play a key role in the economical mass production of graphene membranes used in various applications, such as gas and water purification and electrochemical devices.