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Scalable Bottom-Up Synthesis of Nanoporous Hexagonal Boron Nitride (h-BN) for Large-Area Atomically Thin Ceramic Membranes

Nanopores embedded within monolayer hexagonal boron nitride (h-BN) offer possibilities of creating atomically thin ceramic membranes with unique combinations of high permeance (atomic thinness), high selectivity (via molecular sieving), increased thermal stability, and superior chemical resistance. However, fabricating size-selective nanopores in monolayer h-BN via scalable top-down processes remains nontrivial due to its chemical inertness, and characterizing nanopore size distribution over a large area remains extremely challenging. Here, we demonstrate a facile and scalable approach of exploiting the chemical vapor deposition (CVD) process temperature to enable direct incorporation of subnanometer/nanoscale pores into the monolayer h-BN lattice, in combination with manufacturing compatible polymer casting to fabricate centimeter-scale nanoporous atomically thin ceramic membranes. We leverage diffusive transport of analytes including size-selective Ficoll sieving to characterize subnanometer-scale and nanoscale defects that manifest as pores in centimeter-scale h-BN membranes, overcoming previous limitations in large-area characterization of nanoscale defects in h-BN. Our approach opens a new frontier to advance atomically thin membranes to 2D ceramic materials, such as h-BN via facile and direct formation of nanopores, for size-selective separations.

References:

Naclerio et al. Nano Letters 2025
Naclerio et al. Adv. Mat. 2024
Kidambi et al. Chem. Mat. 2014

Topical Area

Hard matter: energy materials

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