

Ultrathin porous silicon nanomembrane and its water vapor permeation property

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Abstract

A membrane filtration has drawn great attention in many fields of chemistry, biology, energy, and environmental science. Recently many two-dimensional (2D) materials demonstrated rapid permeation property and selectivity of chemical mixtures through their infinitesimal thicknesses^[1]. Silicon-with great chemical stability, intrinsic impermeability, and high hydrophobicity-can be proposed as a new 2D membrane for filtration application by applying adequate porous structure onto nanoscale thickness. However the fabrication process of porous silicon membrane has been constrained to deposition of amorphous silicon with relatively thick (~10nm) membrane^[2]. This study reports on 2nm thick porous silicon nanomembrane and its high water vapor permeance property which can be attributed to its minimum possible thickness. After fabrication of freestanding silicon nanomembrane with ~2nm thickness on a circular hole, nanopores are drilled using helium ion microscope (HIM). The focused helium ion beam enabled perforating aperture 200nm in diameter onto 2nm thick silicon nanomembrane (SiNM) with well-defined aspect ratio (Figure 1). Adopting upright cup method, here we observed exceptionally high water permeance of $\sim 4.1 \times 10^{-5} \text{ mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1} \cdot \text{pa}^{-1}$ through porous SiNM. The measured water vapor transmission rate (WVTR) was about 2 orders of magnitude higher than that of commercial breathable textile membranes (Figure 2) and this value is comparable to

other reported values of carbon based 2D materials^{[1],[3]}.

References

- [1] Celebi, k. et al., Science, 344, (2014) 289-292
- [2] Striemer, C. C. et al., Nature, 445, (2007) 749-753
- [3] Yang, Y., et al., ACS Nano, 12, 5, (2018) 4695-4701
- [4] McCullough, E. A. et al., Meas. Sci. Technol., 14, (2003) 1402-1408

Figures

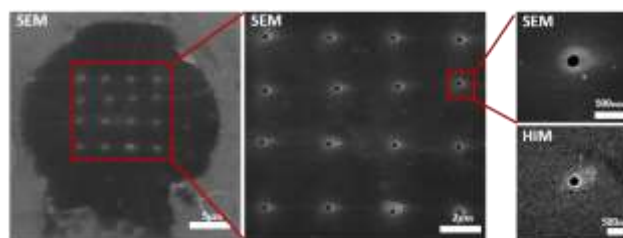


Figure 1: SEM and HIM image of 2nm thick porous Si nanomembrane with 200nm pore diameter

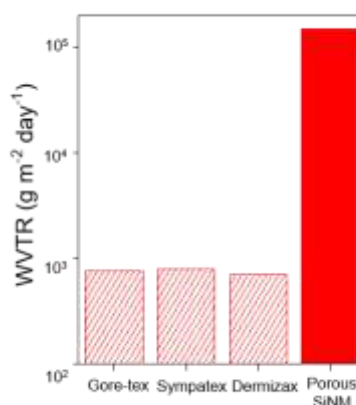


Figure 2: Comparison of WVTR value for porous silicon nanomembrane and waterproof-yet-breathable textile membranes. (data taken from [4])