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Synthesis of wafer-scale single-layer h-BN and its use in proton transport membrane

Proton exchange membranes (PEMs), as semi-permeable membranes, are designed to transport protons while impede other species in hydrogen-based technologies such as redox flow battery [1]. Currently, commercialized PEMs like Dupont's Nafion is largely recognized for its excellent proton conductivity, chemical stability and mechanical strength [2]. However, it generally suffers from relatively poor selectivity, leading to ion crossover issue. This can severely deteriorate the overall performance of electrochemical devices. Recent research on proton conductivity and isotope separation through two-dimensional (2D) atomic crystals in several proof-of-concept works show the great potential of these materials, especially graphene and hexagonal boron nitride (h-BN) [3, 4]. Integration of two-dimensional (2D) hexagonal boron nitride (h-BN) onto commercialized proton exchange membranes (PEMs) can maintain proton conductivity while improve ion selectivity simultaneously, a longstanding issue in separation membrane. However, until now, a cost-effective method for centimeter-scale single-layer h-BN thin film fabrication as well as an efficient method for wafer-scale transfer is still lacking. Here, we use a space-confined approach and Nafion-supporting-Functional Layer-assisted (Nafion-sFLa) transfer method to overcome this roadblock, demonstrating the potency of scale-up as PEMs. Around two inch large single-layer h-BN thin film has been synthesized with high uniformity (Raman peak positions at ~1370 cm^{-1}) and quality (full width at half maximum of ~16 cm^{-1}). With a transfer efficiency as high as 75%, the h-BN functionalized membrane has shown ion selectivity three times higher than that of pristine membrane, reaching more than 30×10^4 S min cm^{-3}. In vanadium flow battery (VFB), the resistance to proton transport of the sandwich membrane is not affected by the h-BN but the barrier properties of h-BN inhibit vanadium crossover at low current density (<100 mA cm^{-2}), resulting in significantly improved coulombic efficiency and energy efficiency, being ~95% and ~92%, respectively. Such Nafion/h-BN/SPEEK sandwich structure may be promising for future 2D materials-based membrane in separation technology.

References

[1] Ding, C.; Zhang, H.; Li, X.; Xing, F., J Phys Chem Lett, 4, (2013), 1281-94.
[2] Mai, Z.; Zhang, H.; Li, X.; Xiao, S.; Zhang, H., Journal of Power Sources, 196, (2011), 5737-5741.
[3] Hu, S.; Lozada-Hidalgo, M.; Wang, F. C.; Mischchenko, A.; Schedin, F.; Nair, R. R.; Hill, E. W.; Boukhvalov, D. W.; Katsnelson, M. I.; Dryfe, R. A.; Grigorieva, I. V.; Wu, H. A.; Geim, A. K., Nature, 516, (2014), 227-30.
[4] Lozada-Hidalgo, M.; Hu, S.; Marshall, O.; Mishchenko, A.; Grigorenko, A. N.; Dryfe, R. A.; Radha, B.; Grigorieva, I. V.; Geim, A. K., Science, 351, (2016), 68-70.

Figures

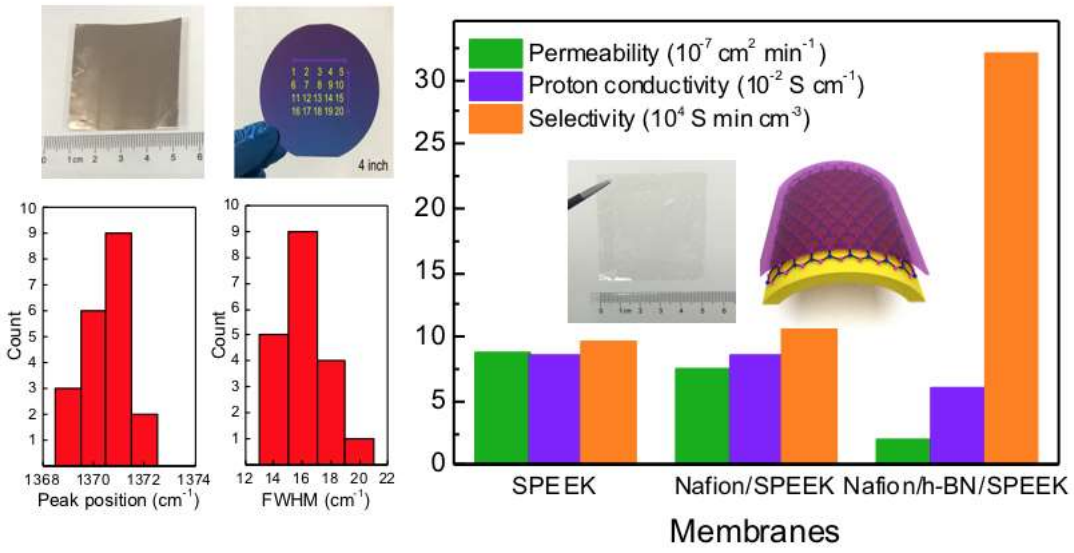

Figure 1: CVD growth of large-area h-BN and its ion transport properties in all vanadium flow battery