Passivation of Phosphorene in Ambient Conditions by Encapsulation with Monolayer Hexagonal Boron Nitride Grown by Chemical Vapor Deposition Technique

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Hexagonal boron nitride (hBN) has attracted a great deal of attention in the past few years not only as a substrate for high-quality atomic-layer devices but also as an ultrathin insulator for passivation and protection of reactive atomic layers. hBN possesses a large bandgap of 6 eV, high mechanical strength, high thermal stability and chemical inertness [1]. Moreover, its monolayer can be easily synthesized and transferred onto different substrates. Hence it makes hBN an excellent candidate as an ultrathin dielectric layer, tunneling barrier, and protective layer.

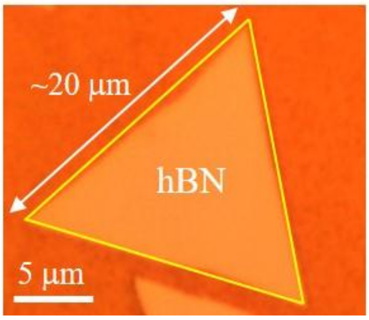

Fig1. Optical images of hBN domains grown on Cu foil

However it is still a great challenge to prepare monolayer hBN with uniform thickness, large grain size and high crystallinity, which is critical for its potential applications. Even though mechanical exfoliation provides highly crystalline hBN flakes, the small size of the flakes seriously limits its application. The preparation of large-area monolayer hBN via exfoliation has been extremely difficult. In contract, the chemical vapor deposition (CVD) technique is a promising method to realize high-quality large-area hBN. In this report, we show the CVD growth of hBN with the use of an electropolished Cu foil as a substrate and hence, its application to successfully passivate exfoliated phosphorene, 2D black phosphorus (BP).

Figure 1 shows a typical optical microscope image of monolayer hBN grains synthesized on a Cu foil, where the weak contrast region corresponds to hBN with lateral size of ~20 μm in edge length. Using the CVD-grown hBN, we demonstrate a facile and general method of encapsulating BP with a dry transfer method. Figure 2a shows AFM image of encapsulated BP after preparation of heterostructure and 2b shows the same BP after a week, which confirms the stability of the encapsulated BPs. This clearly demonstrates that monolayer hBN serves as an ultrathin insulator for passivation and protects reactive atomic layers, BPs, from reacting with oxygen and moisture [2]. The present methodology developed to preserve (otherwise unstable) atomic layered BP flakes from degradation can generally be applied to fabricating BP-based electronic devices in future.

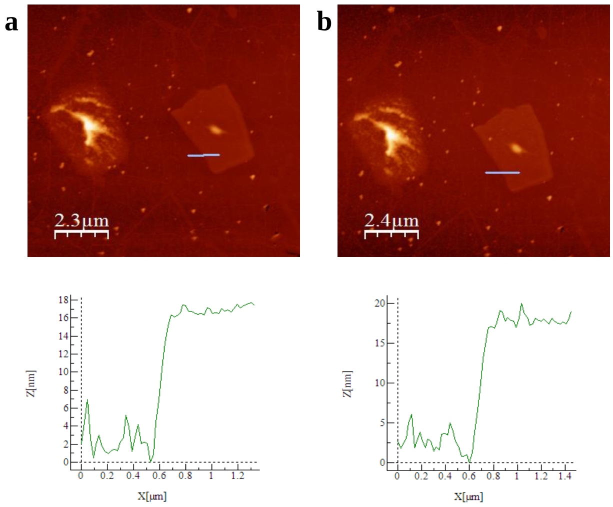

Fig 2(a) AFM image of BP/hBN just after heterostructure fabrication. Fig 2(b) BP/hBN heterostructure after 1 week of exposure to air.

[1] L. Wang *et al. adv. Mater.* **26**, 1559(2013). [2] J. D. Wood *et al. Nano Lett.* **14**, 6964(2014).
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