STM studies of exfoliated black Phosphorus

A. Kumar[1], F. Telesio[1], A. Al Temimy[2], S. Forti[2], C. Coletti[2], M. Serrano-Ruiz[3], M. Caporali[3], M. Peruzzini[3], F. Beltram[1,2], S. Heun[1]

[1]NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, 56127 Pisa, Italy
[2]Center for Nanotechnology Innovation @NEST, Istituto Italiano di Tecnologia, 56127 Pisa, Italy
[3]CNR-ICCOM, Via Madonna del Piano 10, 50019 Sesto Fiorentino, Italy
e-mail: abhishek.kumar@sns.it

After its exfoliation in 2014, black Phosphorus (bP) has emerged as a very interesting material in the category of two-dimensional (2D) materials, due to its properties like layer number-driven band gap tunability and in-plane anisotropy. Until now, scanning tunneling microscopy (STM) studies on this material have been performed only on bulk bP cleaved in-situ [1-3]. A study of thin flakes is more relevant for 2D applications, but it has been limited by the difficulty in preparation of such samples due to their high surface reactivity. We have exfoliated bP on epitaxial monolayer graphene on SiC in a Nitrogen atmosphere in a glove bag which facilitates inert environment for preservation of high sample quality. This is evident by the atomic resolution imaging achieved at room temperature, shown in Fig. 1. We have performed annealing experiments in which we have observed decreasing flake size with increasing temperature. Also the surface quality changes with temperature: the surface roughness increases by an order of magnitude after annealing at 450°C for 2 hours. Upon further annealing at 600°C, almost all flakes desorb from the surface.

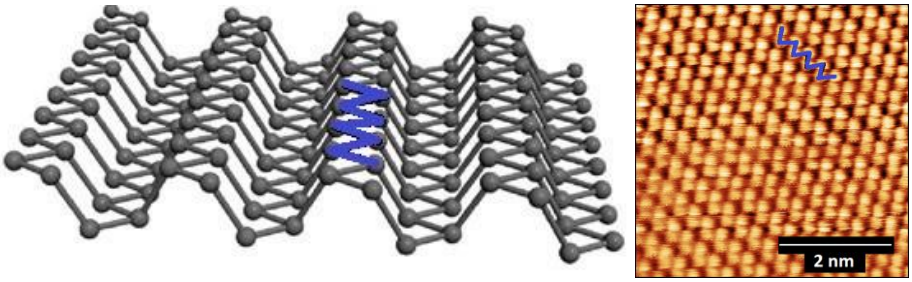

Fig. 1. Left: Phosphorus atom arrangement in a bP monolayer; Right: STM atomic resolution image of the surface of an exfoliated bP flake (zig-zag atomic chain is indicated in blue).

After this initial study, we are now investigating the surface morphological changes with temperature. We have already observed the formation of eye shaped craters on the surface due to atomic desorption after annealing at 375°C, close to the reported value [4,5]. We are further studying the alignment of these craters with respect to the crystallographic direction. These preliminary results will also be presented.

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