Boron can form a purely honeycomb, graphene-like 2-D structure

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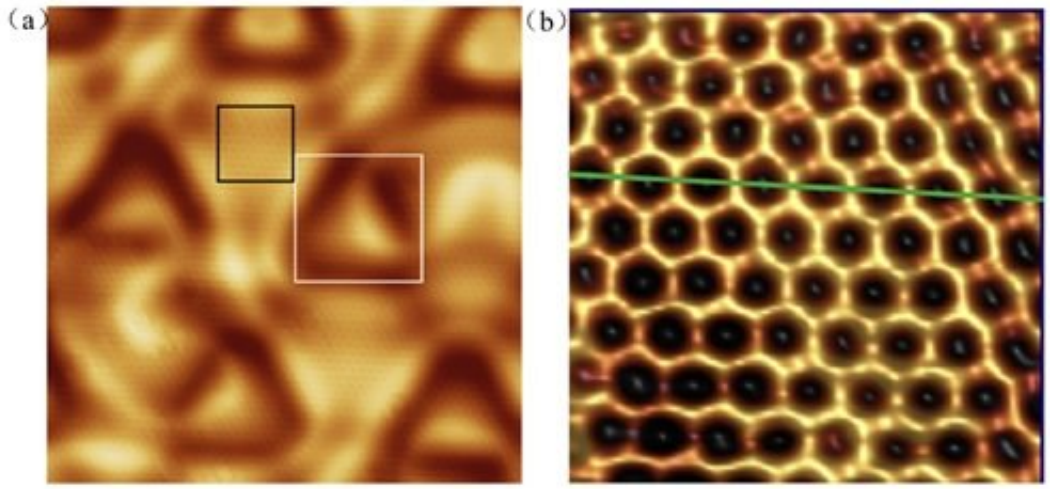

High resolution STM images of borophene monolayer with honeycomb lattice on Al(1 1 1). Credit: ©Science China Press

Borophene is known to have triangular lattice with holes, while a honeycomb lattice of boron was predicted to be energetically unstable. However, a research team led by Prof. K. H. Wu at Institute of Physics, Chinese Academy of Sciences, successfully fabricated a pure graphene-like borophene by using an Al(111) surface as the substrate and molecular beam epitaxy in ultrahigh vacuum, providing an ideal platform for artificial boron-based materials with intriguing electronic properties such as Dirac states and superconductivity behavior.

Low-dimensional boron allotropes have attracted considerable interest in recent decades, and theoretical works predict the existence of monolayer boron. As boron has only three valence electrons, the electron deficiency makes a honeycomb lattice of boron energetically unstable. Instead, a triangular lattice with periodic holes was predicted to be more stable. In 2015, Prof. Wu led a research team at Institute of Physics, Chinese Academy of Sciences, and successfully synthesized 2-D borophene sheets on a silver surface, which exhibit the predicted triangular lattice with different arrangements of hexagonal holes.

An intriguing question is whether it is possible to prepare a borophene monolayer with a pure honeycomb lattice. Honeycomb borophene will naturally host Dirac fermions, and thus, intriguing electronic properties resembling other group IV elemental 2-D materials. Additionally, a honeycomb 2-D boron lattice may enable superconductivity. In the well-known high Tc superconductor, MgB2, the crystal structure consists of boron planes with intercalated Mg layers, where the boron plane has a pure honeycomb structure like graphene. It is remarkable that in MgB2, superconductivity occurs in the boron planes, while the Mg atoms serves as electron donors.

Recently, the research team led by Prof. Wu reported the successful preparation of a honeycomb-shaped graphene-like borophene, by using an Al(1 1 1) surface as the substrate and molecular beam epitaxy (MBE) growth in ultrahigh vacuum. Scanning tunneling microscopy (STM) images reveal perfect monolayer borophene with a planar, non-buckled honeycomb lattice similar to graphene. Theoretical calculations show that the honeycomb borophene on Al(1 1 1) is energetically stable. Remarkably, nearly one electron charge is transferred to each boron atom from the Al(1 1 1) substrate and stabilizes the honeycomb borophene structure. This work demonstrates the manipulation of the borophene lattice by controlling the charge transfer between the substrate and the borophene. And the honeycomb borophene provides

attractive possibility to construct boron-based atomic layers with unique electronic properties such as Dirac states, as well as to control superconductivity in boron-based compounds.

More information: Wenbin Li et al, Experimental realization of honeycomb borophene, *Science Bulletin* (2018). DOI: 10.1016/j.scib.2018.02.006

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