Abstract #99907

Black Phosphorus Field Effect Transistors: Passivation By Oxidation, and the Role of Anisotropy in Magnetotransport

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Abstract Text:

Black phosphorus (bP) is an elemental allotrope with an anisotropic layered crystal structure consisting of a puckered honeycomb lattice that can be mechanically exfoliated down to atomic layer thickness. bP is the most thermodynamically stable allotrope of phosphorus but is nonetheless subject to photo-oxidation in the presence of water, oxygen and visible light with a reaction rate that increases as bP layer thickness decreases [1]. In the first part of my talk, I will describe our experiments showing how oxidation can be used for passivation of black phosphorus field effect transistors. In the second part of my talk, I will describe magnetotransport measurements of black phosphorus transistors and their relation to the anisotropy of the bP crystal lattice.

Motivated by the experimental observation that reactive ion etching produces a phosphorus oxide / black phosphorus interface that does not inhibit photo-luminescence yield [2], we have fabricated bP field effect transistors with an encapsulating phosphorus oxide layer that acts as a passivation layer. X-ray photoemission spectroscopy (XPS) reveals the oxide layer to have a P_20_5 stoichiometry. Air stable, top gated bP field effect transistors with room temperature field effect mobilities exceeding 100 cm^2/Vs are demonstrated using a gate oxide formed by reactive ion etching and subsequent atomic layer deposition of aluminum oxide.

We have also investigated the magnetotransport properties of black phosphorus at modest fields. Weak localization was observed in a black phosphorus field-effect transistor 65 nm thick [3]. The weak localization behavior was found to be in excellent agreement with the Hikami-Larkin-Nagaoka [4] model for fields up to 1 T, from which characteristic scattering lengths could be inferred. The temperature dependence of the phase coherence length L_ϕ was investigated, and above 1 K, it was found to decrease weaker than the $L_\phi \sim T^{-1/2}$ dependence characteristic of electron-electron scattering in the presence of elastic scattering in two dimensions. Rather, the observed power law was found to be close to that observed previously in quasi-one-dimensional systems such as metallic nanowires [5] and carbon nanotubes [6]. The potential role of strong in-plane anisotropy resulting from a puckered honyecomb structure on localization will be discussed.

[1] A. Favron et al., Nat. Mater. 14, 826 (2015).

[2] J. Pei et al., Nat. Comm. 7, 10450 (2016).

[3] N. Hemsworth et al., Phys. Rev. B 94, 245404 (2016).

[4] S. Hikami et al., Prog. Theor. Phys. 63, 707 (1980).

[5] D. Natelson et al., Phys. Rev. Lett. 86, 1821 (2001).

[6] J. Appenzeller et al., Phys. Rev. B 64, 121404(R) (2001).

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