Strong anisotropic in-plane magneto-transport in a few-layer bP FET

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Since its re-discovery in 2014 as a van der Waals material suitable for mechanical exfoliation, black phosphorus (bP) has attracted great interest, mostly due to its direct band gap that depends on the number of layers, as well as its strong in-plane anisotropy. This latter property is caused by the puckered structure of the individual bP planes forming the atomic crystal, see Fig. 1(b). This anisotropy has been observed in its optical, thermal, and electronic transport properties [1,2], as well as in quantum-interference effects such as weak localization [3].

Previous magneto-transport focused mainly on the Shubnikov-de Haas oscillations [4] and on the quantum Hall effect [5]. Here, we report in-plane magneto-resistance measurements of few-layer bP forming a field-effect transistor, see Fig. 1(c). The resistivity was determined as a function of the angle between the in-plane magnetic field and the crystallographic axis of the bP flake, as determined by polarized Raman spectroscopy. The observed in-plane magnetoresistance is found to be as large as 10%, is strongly anisotropic, and it varies non-monotonically with increasing field up to 45T (at a fixed angle), shown in Fig. 1(a). The conventional theory of magneto-resistivity drastically fails to account for the behaviour observed at such large fields. In this regime, the magneto-resistance exhibits clear maxima (minima) when the magnetic field is aligned along the zig-zag (armchair) axis. Taking anisotropy into account and introducing a correction for the carriers' velocity due to the Lorentz force, a model was developed that remarkably captures the essence of this anisotropic magneto-resistive effect.

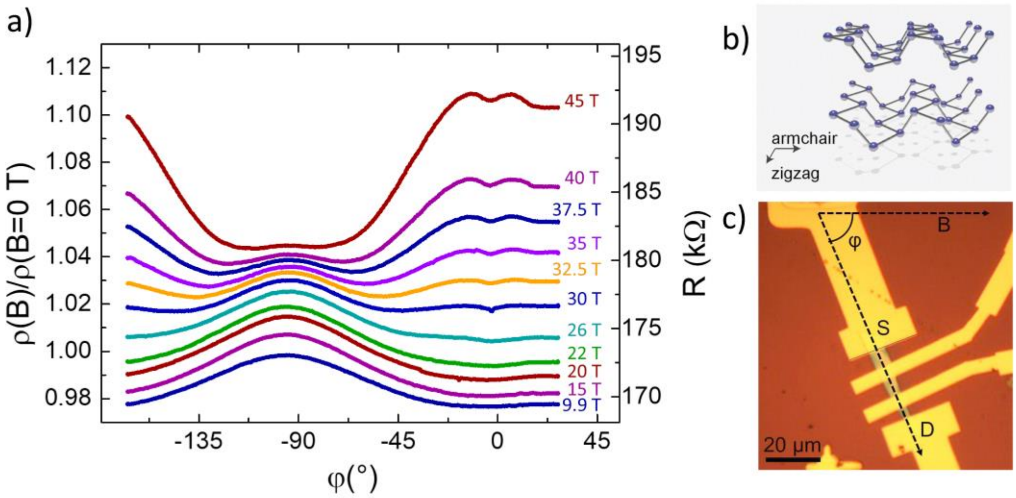

FIG. 1. (a) Low-temperature in-plane magneto-resistance as a function of azimuthal angle φ between the device axis and magnetic field vector. (b) Sketch of bP crystal structure with crystallographic directions indicated. (c) Optical microscopy image of the device with source (S) and drain (D) indicated. The angle φ is indicated.

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