ISGD-5

5th INTERNATIONAL SYMPOSIUM ON GRAPHENE DEVICES

Electronic Properties of High-Quality Epitaxial Topological Dirac Semimetal Thin Films

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Highlight statement: Topological Dirac semimetals are new materials with linear electronic dispersions, similar to graphene, but in three dimensions. Here we demonstrate the first growth and characterisation of the electronic properties of large area (1cm x 1cm) Na_3Bi thin films grown on insulating substrates.

Topological Dirac semimetals (TDS) are three-dimensional analogues of graphene, with linear electronic dispersions in three dimensions. Electrical measurements so far have been on bulk TDS crystals and have revealed unusual axion magnetoresistance [1]. Yet the ability to grow and characterise TDS thin-films on thickness scales ranging from several monolayers to tens of monolayers with transport and scanning tunnelling microscopy (STM) opens up numerous new possibilities, including studying the conventional-to-topological quantum phase transition (QPT) as a function of layer thickness or incorporating gate electrodes to enable an electric field-tuned QPT, realizing a topological transistor [2].

We combine molecular beam epitaxial growth with a low-temperature STM capable of magnetotransport at 5 K to study the electronic properties of Na_3Bi thin films. Thin films (20 nm) of Na_3Bi on α-Al_2O_3(0001) substrates are found to possess low temperature charge carrier mobilities exceeding 6000 $cm^2V^{-1}s^{-1}$ with n-type carrier densities below 1 x 10^{18} cm^{-3} that are comparable to the best single crystal values [3]. Perpendicular magnetoresistance at low field shows the perfect weak-antilocalization behaviour expected for Dirac fermions in the absence of intervalley scattering. Efforts to reduce the intrinsic *n*-type doping via the introduction of molecular surface acceptors to reach the charge neutrality point will also be discussed [4].

[1] J. Xiong et al., Science 350, 413 (2015)

[2] X. Xiao, et al., Scientific Reports 5, 7898 (2015)

[3] J. Hellerstedt, M. T. Edmonds, N. Ramakrishnan, C. Liu, B. Weber, A. Tadich, K. M. O'Donnell, S. Adam, M. S. Fuhrer (submitted)

[4] J. Hellerstedt, A. Tadich, K. M. O'Donnell, M. S. Fuhrer, M.T. Edmonds (in preparation)