Visualising electronic structure in 2D heterostructures

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Two-dimensional heterostructures (2DHSs), made by stacking atomically thin layers of different two-dimensional materials (2DMs), are an exciting playground for condensed matter physics. 2DMs are characterised by strong in-plane bonding with weak interactions between layers. This allows the fabrication of atomically clean interfaces by simply peeling and stacking. With the large family of 2DMs that are now available, including metals, semi-metals, semiconductors, superconductors, magnets etc., this opens the possibility of designing a limitless range of 2DHSs. The weak interactions between the layers in the stack mean that, to a first approximation, the properties of the individual layers can be retained unaltered. Hence, the highest mobilities measured in graphene come when sandwiching it between layers of hexagonal boron nitride (a wide-band gap semiconductor that is an effective dielectric) and integrating graphite top and bottom gate electrodes in an all 2D device. However, the interlayer interactions can play important roles and are often dependent on the relative crystallographic alignment of the layers, the twist angle between them, giving rise to the new field of 2D twistronics. For example, at a 'magic angle', interactions between two layers of graphene can introduce flat bands near the Fermi level, resulting in observations of Mott insulator and superconducting states accessible by electrostatic doping. Understanding and measuring the electronic structure of the 2DMs, the changes in electronic structure due to inter-layer interactions in 2DHSs, and the effect of electrostatic doping, are essential to progressing the field. In this talk I will present some of our recent work [1–3] on directly measuring electronic structure in 2DHSs by spatially-resolved angle resolved photoemission spectroscopy (nanoARPES).

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[2] P. V. Nguyen, N. C. Teutsch, N. P. Wilson, J. Kahn, X. Xia, A. J. Graham, V. Kandyba, A. Giampietri, A. Barinov, G. C. Constantinescu, N. Yeung, N. D. M. Hine, X. Xu, D. H. Cobden, and N. R. Wilson, Nature **572**, 220 (2019).

[3] A. J. Graham, J. Zultak, M. J. Hamer, V. Zolyomi, S. Magorrian, A. Barinov, V. Kandyba, A. Giampietri, A. Locatelli, F. Genuzio, N. C. Teutsch, C. Salazar, N. D. M. Hine, V. I. Fal'ko, R. V. Gorbachev, and N. R. Wilson, 2D Mater. **8**, 015016 (2020).