

Twisted graphene layers under heterostrain

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Stacking layered materials is a very powerful method to tailor their optical and electronic properties. The properties not only depend on the choice of materials to be stacked but also on the details of the relative arrangement of the layers. For instance, the rotation between the layers has been used to tune the energy of van Hove singularities in twisted graphene layers [1] or to observe the Hofstadter butterfly pattern in graphene on h-BN [2,3]. An even more impressive demonstration of the possibilities offered by precise tuning of the relative arrangement is the recent observation of correlated insulating and superconducting behaviour in magic angle twisted graphene layers[4,5].

Besides rotation, van der Waals stacking offers another possibility to adjust the relative arrangement of the layers: individual stretching of the layers (so-called heterostrain). In the present contribution we will expose scanning tunnelling measurements exploring this possibility in twisted graphene layers[6]. We will show that uniaxial stretching of one layer by only 0.36% with respect to the other layer can dramatically affect the electronic properties of twisted graphene layers with low rotation angle. The amount of heterostrain is determined by a detailed Fourier analysis[7]. With such a low level of heterostrain, we observe a pronounced peak in the density of states at the Dirac energy which we attribute to the emergence of a flat band similar to that observed at magic angles. The strain-induced modification of the band structure could therefore prove useful for the study of the recently discovered correlated electron physics in carbon materials. More generally heterostrain opens up new possibilities for straintronics with 2D materials.

- [1] G. Li *et al.* Observation of Van Hove singularities in twisted graphene layers *Nature Phys.* **6** 109 (2009)
- [2] G. Li *et al.* Cloning of Dirac fermions in graphene superlattices *Nature* **497** 594 (2013)
- [3] C. R. Dean *et al.* Hofstadter's butterfly and the fractal quantum Hall effect in moiré superlattices *Nature* **497**, 598 (2013)
- [4] Y. Cao *et al.* , Unconventional superconductivity in magic-angle graphene superlattices *Nature*, London (In press)
- [5] Y. Cao *et al.* , Correlated insulator behaviour at half-filling in magic-angle graphene superlattices *Nature*, London (In press)
- [6] L. Huder *et al.* *Phys. Rev. Lett.* (In press)
- [7] A. Artaud *et al.* *Sci.Rep.* **6**, 25670 (2016)