Intrinsic roughness of van der Waals heterostructures

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Roughness in two dimensional materials limits electronic performance due to increased scattering. Graphene may exhibit roughness by conforming to surface – for example silicon dioxide [1] – or by intrinsic ripples or corrugations in the suspended state [2]. Such ripples are a suspected key source of scattering and limiting carrier mobility in clean graphene samples [3]. Elimination of roughness is therefore an important technological goal.

Suspending graphene flakes has proven to increase the electron mobility drastically compared to graphene supported on silicon oxide [4], as adverse effects on the mobility from the silicon oxide is eliminated. Similar improvements in mobility are obtained by encapsulating the graphene in hexagonal boron nitride (hBN) [5].

Here we have fabricated graphene samples encapsulated by hexagonal boron nitride (hBN) and suspended over apertures in a substrate and used non-contact electron diffraction measurements [6] in the transmission electron microscope to measure the roughness of graphene in such structures for the first time. We report the lowest graphene roughness achieved to date at 12 pm obtained for suspended hBN encapsulated graphene. The roughness of graphene on suspended hBN was < 25 pm, similar to previous work for graphene on mica, while less than that typically observed for graphene on hBN supported by a substrate [7]. First principles calculations support the idea of a heterogeneous partitioning of phonon energies between the hBN and graphene, with the flexural acoustic phonon mode localized predominantly in the hBN layers. These results may lead to new fabrication strategies for optimising electronic properties of 2D materials, since suspended heterostructures may be flatter than heterostructures placed on SiO_2.

References

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Figures

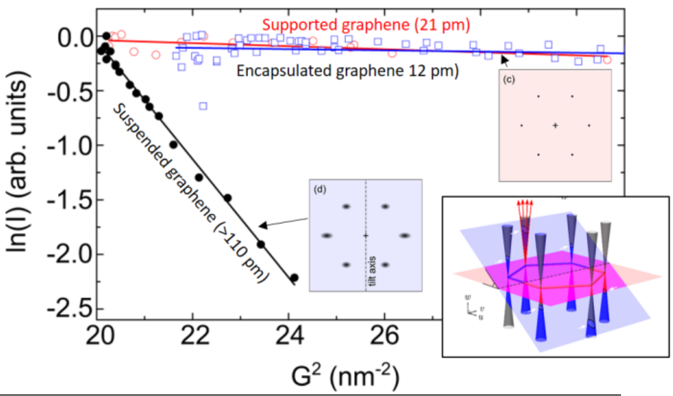

Figure 1: Diffraction patterns of tilted samples shows that encapsulated graphene have exceptionally low roughness down to the 12 pm.