Analysis of graphene-hBN heterostructures by high-resolution scanning transmission electron microscopy with direction-sensitive detection of scattered electrons

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In recent years, heterostructures of 2-D materials have gathered significant attention [1]. Since graphene and hBN have nearly the same lattice constant, structural distortions can appear if the orientation of the lattices is aligned [2]. Here, we investigate a free-standing, orientationally aligned graphene and single-layer hBN heterostructure by electron microscopic methods. In particular, we used electron diffraction and dark-field TEM imaging to evaluate the global structure as well as aberration-corrected scanning transmission electron microscopy (STEM) to study the local atomic arrangements. Besides standard annular dark field (ADF) imaging, we developed a detection scheme where a pixelated detector is used to record not only the total scattered intensity but also the direction of the scattered intensity in its angle and magnitude. This signal is very sensitive to the relative position of atoms on top of each other in the two layers of the sample, as verified also by simulated data. Fig. 1 shows a medium-angle ADF image of a heterostructure with only 1° orientational misalignment. Different local stacking configurations can be identified within the moiré. AB stacked regions consistently appear larger than AA or AB' stacked areas, which is clear evidence for a structural distortion due to the interaction between the layers. Current work in progress is to reconcile these observations with theoretical models, in order to understand the in-plane (shear, strain) and out-of-plane (bending) components of the observed distortion as well as to gain insight to the underlying interaction between the sheets.

[1] A. Geim, I. V. Grigorieva, Nature **499** (2013) 419.
[2] Woods, C. R. et al. Nature Phys. **10**, (2014) 451.

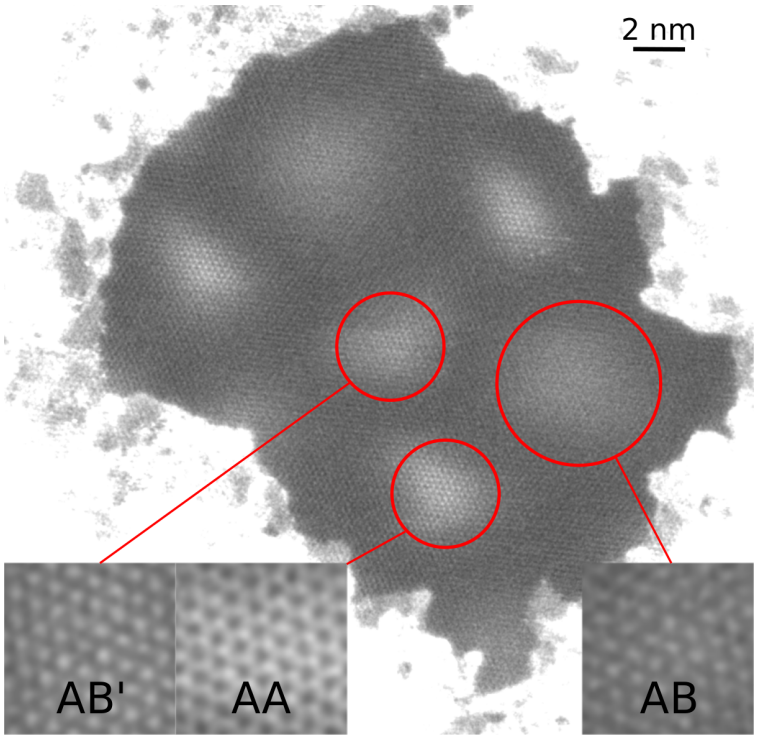

Figure 1: ADF image of a graphene-hBN heterostructure and high-resolution close-ups on different local stacking. The AB stacked regions (carbon and boron aligned) are larger than AA and AB' regions.