# Probing the electronic coupling between atomically thin layers in van der Waals systems

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Many layered materials can be mechanically exfoliated, down to atomically thin sheets. This opens the possibility to stack different layers together to form systems with novel properties: the so-called van der Waals (vdW) materials. To create materials with custom-designed properties in the future, understanding the quantum overlap between the different layers is key. Here, we investigate interlayer interactions using a novel technique, focusing on graphene and hexagonal boron nitride (hBN).

Experimentally, the occupied bands can be routinely measured by ARPES (angle-resolved photo-emission spectroscopy). However, it has been remarkably difficult to characterize the (dispersion of the) empty part of the band structure. We have developed a method to do just that, based on low-energy electron microscopy (LEEM) [1]. The technique, coined angle-resolved reflected-electron spectroscopy (ARRES), relies on the dependence of the reflectivity of low-energy electrons on both their kinetic energy and their incident angle on the sample. It has a high cross-section and a spatial resolution of $\sim$10 nm, which is five orders of magnitude better than other techniques. The latter allows us to scrutinize even small flakes of vdW materials. Applying ARRES to flakes of few-layer graphene and hBN separately, we find quantization of the conduction band into well-defined interlayer states for both systems. These interlayer states have a similar dispersion and very similar energies for the two materials. Nevertheless, in a stack of graphene on hBN, we observe no coupling of the electronic systems of the two materials despite their intimate contact. This substantiates that hBN is an excellent substrate to isolate graphene from its environment over a wide energy range [2].

The possibility to perform both ARRES and local ARPES (angle-resolved photo-emission spectroscopy) will give us the opportunity to investigate band structure formation in a large range of vdW systems in the near future. Knowledge on this is crucial to tailor the properties of van der Waals crystals, stacked in a LEGO-like fashion.

[1] J. Jobst, et al., Nature Communications 6, 8926 (2015)

[2] J. Jobst, et al., Nature Communications 7, 13621 (2016)