Kolloquium

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Probing interlayer interaction in van der Waals materials

physikalisches

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Many layered materials can be mechanically exfoliated to atomically thin sheets, the most famous being graphene. This opens the possibility to stack different layer types together to form materials with novel properties: van der Waals (vdW) systems. The extent to which vdW systems differ from the mother materials is governed by the interaction between the different layers. Here, we investigate interlayer interactions using several new techniques developed in our lab.

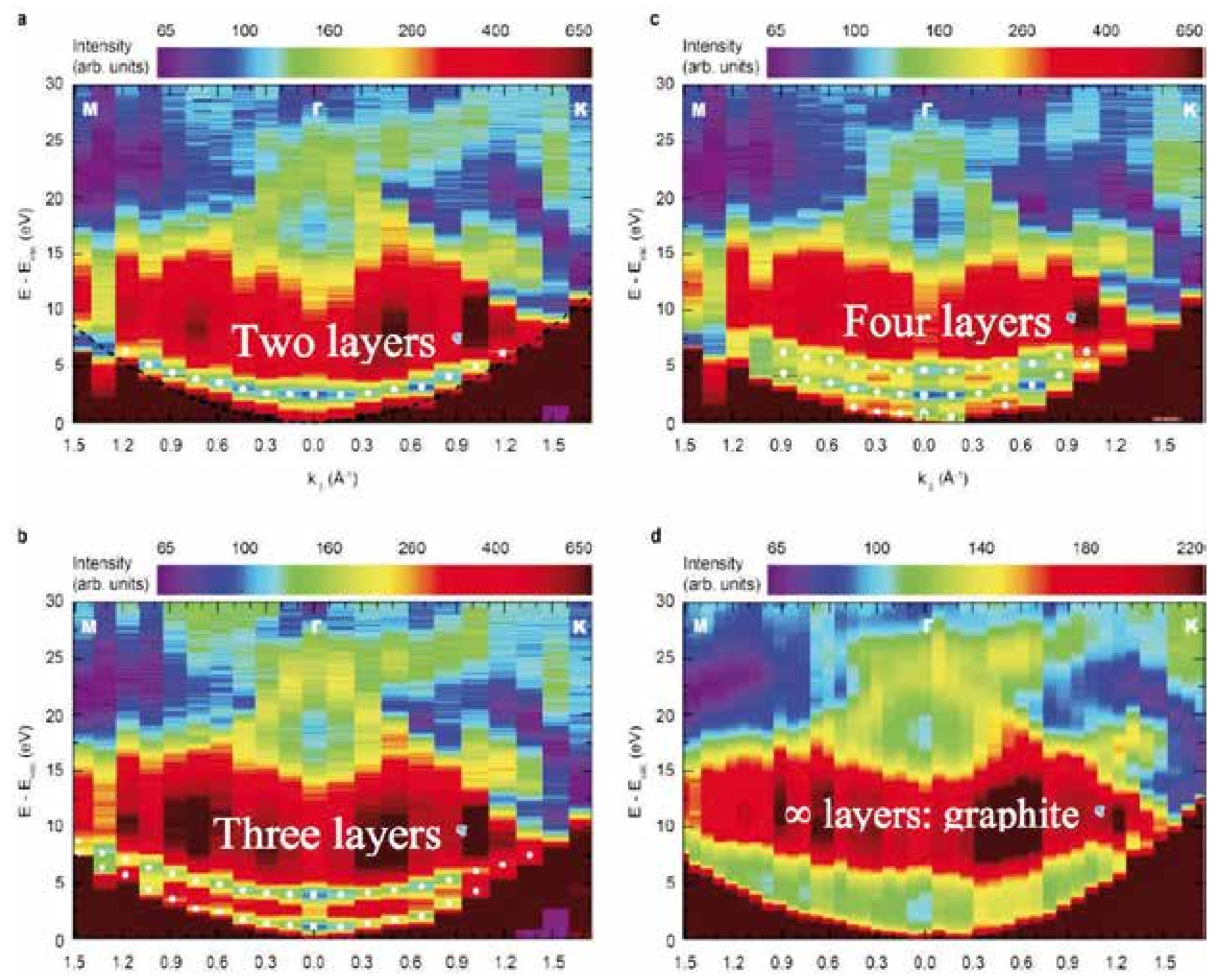
At the basis is a low-energy electron microscope (LEEM). With this unique instrument, we probe the reflection of electrons with tunable energies of 0-100 eV. Not only does this allow for microscopy, with 1.4 nm resolution, it also enables us to do local spectroscopy. Moreover, we have recently extended our instrument with a groundbreaking form of transmission electron microscopy (eV-TEM), which probes at extremely low electron energies (0-30 eV).

We apply both LEEM and eV-TEM to graphene layers of varying thickness. With every additional layer of graphene, an (unoccupied) interlayer state is added, which hybridizes with the other interlayer states. In electron reflection, the resulting eigenstates appear as minima in the spectrum R(E). In a transmission spectrum T(E), however, they show up as resonant maxima, reminding us of the energy-dependent Landauer formula for electron transport. From both functions, we can quantitatively determine the hybridization energies of the overlapping states.

To substantiate this further, we study the 2D-dispersion relations of these unoccupied bands. For that, we have developed a novel technique, coined angle-resolved reflected-electron spectroscopy (ARRES) [1]. Applying ARRES, we investigate simple Van der Waals materials consisting of flakes of few-layer graphene (Fig. 1) and h(exagonal) BN separately, as well as their combination. Interestingly, we find virtually no hybridization between hBN and graphene layers. [2]

Summarizing, we have created a unique possibility to investigate (unoccupied) band structure formation in a large range of vdW systems. Knowledge on this is crucial to tailor the properties of such layered materials, as they are built up 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)



Above: ARRES maps of multilayer graphene. The number of interlayer states, which show parabolic dispersion, increases with thickness. [1]