Electronic Properties of van der Waals Heterostructures Covered with Graphene

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Two-dimensional materials provide a versatile platform for designing hybrid systems with electronic properties that are not attainable in their individual bulk or monolayer forms. In particular, van der Waals heterostructures enable the controlled combination of layered compounds without the constraints imposed by conventional chemical bonding. As a result, their interfaces may host modified electronic states, charge redistribution, and coupling effects that strongly influence the behavior of the entire system. In this talk, I will discuss the electronic structure of graphene-covered van der Waals heterostructures based on selected surface-sensitive materials, including the charge-density-wave compound TaS_2, the topological insulator Bi_2Se_3, and the Weyl semimetal WTe_2. The main focus will be placed on how graphene modifies, protects, and electronically interacts with these materials, and how interlayer coupling affects the electronic properties of both the graphene overlayer and the underlying substrate.

The experimental findings are interpreted with the support of first-principles calculations based on density functional theory, allowing us to identify the microscopic origin of the observed interface-driven effects. In addition, machine-learning-assisted analysis is used to process and classify experimental data, providing further insight into charge transfer, band-structure modifications, and the evolution of electronic properties in graphene-covered van der Waals systems. Together, these results demonstrate how graphene can serve not only as a protective layer, but also as an active component in engineering the electronic response of hybrid two-dimensional materials. This work was financially supported by the National Science Centre, Poland under project 2018/30/E/ST5/00667.

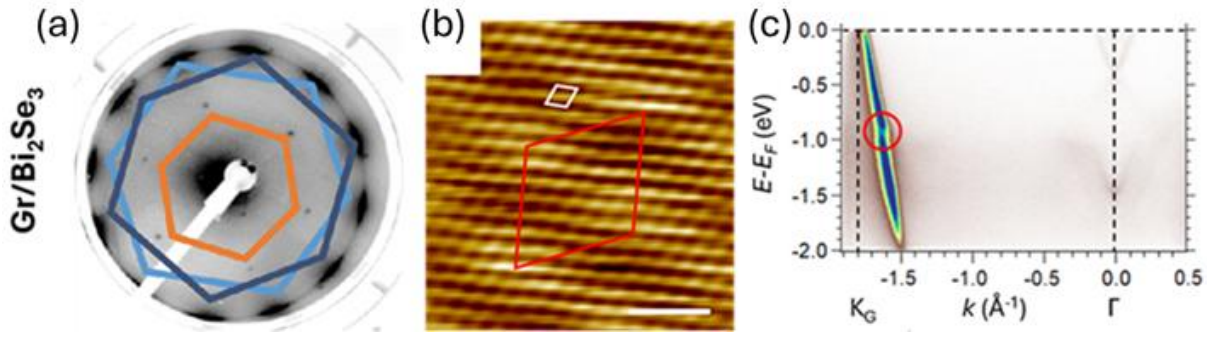

Fig. 1. Experimental results for the van der Waals heterostructure graphene/Bi_2Se_3: (a) Low-Energy Electron Diffraction (LEED), (b) Scanning Tunneling Microscopy (STM) and (c) Angle-Resolved Photoemission Spectroscopy (ARPES).