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Electronic Structure and Electron Dynamics in Single-Layer Transition Metal Dichalcogenides

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The size of a band gap determines the suitability of a material for use in different applications such as computers or in solar cells. In the case of artificial two-dimensional (2D) materials, such as graphene or single-layer (SL) transition metal dichalcogenides (TMDCs), electronic properties, including the band gap, are drastically different from their parent compounds, where dimensionality is not reduced.

The electronic properties of 2D materials do not only depend on the material, but also on its environment, for example, the substrate it is placed on. By changing the dielectric properties of the substrate or the carrier concentration in the material, the band gap size can be modified. Besides control of the band gap, control of the spin- and valley-degrees of freedom has been suggested as a new, potential tuning knob for carrier dynamics, and SL TMDCs, such as SL MoS2 and WS2, are particularly promising candidates for new spin- and valley-tronic devices. This is due to the breaking of the inversion symmetry in their crystal lattice, a strong spin-orbit coupling, and a direct band gap at the K and K' valleys in their electronic structures.

In order to obtain information about ultrafast carrier dynamics and valley-degrees of freedom, it is necessary to probe the samples in a manner that can provide both time and angular resolution. The time- and angle-resolved photoemission spectroscopy (TR-ARPES) technique provides exactly that. TR-ARPES is, however, limited by the technical requirement for high photon energies, since the interesting part of the aforementioned materials' electronic structures is located at the 2D Brillouin zone boundary. This technical limitation was recently overcome with the arrival of ultrafast high harmonic laser sources. These sources can be used to directly access the size and character of the electronic band gap in a semiconducting 2D material, while in the case of 2D metallic layers, the effect of the low dimensionality on electronic instabilities such as charge density waves and superconductivity can be investigated.

This talk will cover single layers of MoS2, WS2 and TaS2 epitaxially grown on Au(111), Ag(111) and graphene. Furthermore, technical requirements, the experimental system and growth procedures will be presented, along with the future experimental directions.

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