THESIS DEFENSE
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Thursday, March 25th 2021 at 2.30PM

Online

Electron Dynamics in Layered Materials

Currently, layered materials attract great interest due to their electrical and optical properties. Such crystals can be thinned down to the single layer and display an electronic band structure that strongly depends on the sample thickness. The large tunability of the electronic screening and gap size can be very attractive for the creation of heterostructures whose properties can be designed on demand. These goals motivate the renewed attention to compounds that were known for many years. We can say that the research field of low dimensional materials has been boosted by the discovery of graphene and quickly has been enlarged to other materials like transition metal dichalcogenides, black phosphorous and Indium selenide. Our work will focus on the excited state dynamics in these compounds, as well as on the evolution of the band structure upon surface doping. The TrARPES measurements of layered black phosphorus (BP) monitor the electronic distribution in the conduction and valence band as a function of delay time from photoexcitation. The data show that, after thermalization, the photo-injected electrons do not lead to sizable bandgap renormalization, neither do they generate an appreciable amount of carrier multiplication. On the other hand, a Stark broadening of the valence band is ascribed to the inhomogeneous screening of a local potential around charge defects. We show time-resolved ARPES data on a BP surface that is doped in-situ by means of alkali metals evaporation. We monitor the collapse of the band-gap in the accumulation layer with unmatched accuracy and we observe that the buried states detected by the low energy photons of our probing pulse acquire a surprisingly high band velocity at large dopants concentration. We also deal with the modification of hot carrier dynamics upon increasing the surface doping of BP. In this case, the reported analysis is still preliminary and needs to be backed by ab-initio calculations. As in the case of BP, we generate an accumulation layer of varying electronic density on the surface of such semiconductors. By spanning the doping level from the semiconducting to the metallic limit, we observe that quantum screening of Longitudinal Optical (LO) phonons is not as efficient as it would be in a strictly bidimensional system, indicating a remote coupling of confined states to polar phonons of the bulk. Furthermore, we show that a 3D Fröhlich interaction with Thomas-Fermi screening can be used to mimic the effects of such a remote coupling at the ε-InSe surface. Furthermore, we study the layered 1T-TaS2. This material belongs to the Charge Density Waves (CDW) systems and has been extensively investigated by several research groups. In 1T-TaS_2, the combination of structural distortion with high electronic correlations leads to a complex and fascinating phase diagram. In future work, we could reproduce controversial data that have been recently published in the literature and that identifies a new instability in the proximity of the metal to-insulator transition.

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