Scientific and technological opportunities with emerging two-dimensional ferroelectric semiconductors

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The electronic band structure of a semiconductor crystal underpins its physical and chemical properties. Unlike traditional semiconductors with imperfect surfaces, the emergent class of van der Waals (vdW) semiconductors can be readily cleaved or exfoliated to reveal high quality surfaces ideally suited to the imaging and tuning of band structures. Here, we utilise angle-resolved photoemission spectroscopy and high magnetic fields to reveal the unique band structure of the van der Waals semiconductor In_2Se_3, a ferroelectric material of broad interest for science and technologies [1].

As in many III-VI compounds, the electronic band structure of In_2Se_3 undergoes changes in the transition from the bulk to the single layer. In many III-VI semiconductors, such as InSe, this transition is accompanied by the emergence of a ring-shaped valence band maximum referred to as an inverted Mexican hat or camelback dispersion with hole effective masses much heavier than in traditional semiconductors [2]. In contrast, we show that this unusually shaped band exists in bulk In_2Se_3 and that it can be tailored by the specific polymorph [3] and stacking (1T, 2H and 3R) of the vdW layers. The significance of this unusually shaped band and the ability to modify it are motivated by the possibility to create new forms of magnetic and charge order driven by weakly screened electron correlations. Thus, these results provide the foundation for band engineering of carrier correlations for emerging technologies. Finally, we report on ferroelectric semiconductor junctions in which the ferroelectric In_2Se_3 is embedded between two single-layer graphene electrodes. In these two-terminal devices, the ferroelectric polarization of the nanometer-thick In_2Se_3 layer modulates the transmission of electrons across the graphene/In_2Se_3 interface, leading to memristive effects that can be controlled by applied voltages and/or by light [4].

References

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[2] Bandurin et al. Nature Nanotechnology (2017) 12, 223
[3] Yan et al. Advanced Functional Materials (2021) 2106206
[4] Xie et al. 2d Materials (2021) 8, 045020