

Valley Physics in Transition Metal Dichalcogenide 2D crystals

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Abstract

2D crystal of transition metal dichalcogenide (TMD) is a unique spin-orbit system with valley degree of freedom. The monolayer TMD has a honeycomb structure with a multi-valley band structure at the edges of the Brillouin zone, K and K' points, in a similar manner to graphene. Due to the absence of in-plane inversion symmetry, the gap is opened providing TMD based 2D crystals with an opportunity of interaction with visible light and thus optical or optoelectronic functions which are basically absent in graphene. Also, the valence band top at the K points are spin split with 0.1 – 0.4 eV due to the large spin-orbit interaction [1]. A peculiar feature of the TMD monolayer is that the K and K' points have different chirality which can be controlled and detected by various external stimuli such as light, voltage, and magnetic field. In this presentation, a short review will be made on the basic spin-valley and related properties and valleytronic functionalities in TMD materials.

First, we found the valley dependent Zeeman-type out-of-plane spin polarization using spin- and angle resolved-photoemission spectroscopy in MoS₂ [2], which is fully consistent with a theoretical prediction [1]. This became possible by choosing noncentrosymmetric bulk crystals, so called 3R polytype. Photoluminescence circular dichroism proved that the noncentrosymmetric stacking effectively preserves the information of valley polarization even in multilayers, indicating that the noncentrosymmetric MoS₂ crystals are useful materials for the future valleytronics.

Field effect transistor (FET) plays crucial roles in the control of spin-valley degrees of freedom. We demonstrate FET related new functionalities, including gate-controlled Zeeman-type spin splitting [3], an ambipolar FET [4], and electric field induced superconductivity [5] with an enhanced Pauli pair breaking limit due to the Zeeman-type spin polarization. Finally, we demonstrate the electrically switchable chiral light source, an electro-optical conversion device [6].

References

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