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Electric Control of Spin-Coupled Valleytronics in Layered Metal Dichalcogenides

Abstract

Recent efforts on two-dimensional atomic layer materials, aiming at novel electronic properties and quantum phenomena beyond graphene, have attracted much attention for potential electronics/spintronics applications. Compared to the weak spin-orbit-interaction (SOI) in graphene, layered transition-metal chalcogenides MX2 (M = Mo, W; X = S, Se, Te) have heavy 4d/5d elements with strong atomic SOI, providing a unique way to extend functionalities of novel spintronics and valleytronics devices based on valleytronics physics by considering the valley degree of freedom in MX_2 dichalcogenides. For example, in WSe_2, with a layered honeycomb lattice and two inequivalent valleys in the k-space electronic structure in the hexagonal Brillion zone, due to the large separation of valleys in k-space and the resulting suppression of intervalley scattering, the valley index can be used in analogy to the spin in spintronics, opening a new research direction called 'valleytronics'. Such a valley polarization achieved via valley-selective circular dichroism has been predicted theoretically and demonstrated with optical experiments in those MX_2 systems.

However, despite this exciting progress, the following two important issues in MX_2 valleytronics community remain elusive: 1) The most current understanding of their electronic structures is based on either theoretical investigations or indirect experimental techniques (*e.g.* optical measurements), leaving the detailed band structures elusive, especially the valley location (the band maxima/minima) in the BZ have not been experimentally confirmed yet. Therefore a direct detection for band dispersion becomes of great importance for valleytronics especially for those cleaved ultrathin mono- and bi-layer flakes hosting most of recently-reported exotic phenomena in the 2D limit. 2) The generation of a valley/spin current by the valley polarization in MX_2 remains elusive and a great challenge. A spin/valley current in MX_2 compounds caused by such a valley polarization has never been observed, nor its electric-field control.

In this talk, we will present the following topics: we will show the basic electronic structure of representative MX_2, obtained by angular resolution photoemission spectroscopy (ARPES), and investigate both the variation of the band minima/maxima (the valley locations) between these compounds and their band evolution from bulk to the monolayer limit. After having a systematic understanding of the band structure, we will demonstrate, within an electric-double-layer transistor based on WSe_2, the manipulation of a spin-coupled valley photocurrent whose direction and magnitude depend on the degree of circular polarization of the incident radiation and can be further greatly modulated with an external electric field. Importantly, the spin photocurrent can be realized based on both the inter-band band excitation mechanism and also the intra-band excitation mechanism. Such room temperature generation and electric control of valley/spin photocurrent provides a new property of electrons in MX_2 systems, thereby enabling new degrees of control for quantum-confined spintronics devices.

References

[1] H. T. Yuan, X. Q. Wang, B. Lian, H. J. Zhang, X. F. Fang, B. Shen, G. Xu, Y. Xu, S.-C. Zhang, H. Y. Hwang and Y. Cui. ***Nature Nanotech. 9***, 851-857 (2014).

[2] H. T. Yuan, M. B. Saeed, K. Morimoto, H. Shimotani, K. Nomura, R. Arita, Ch. Kloc, N. Nagaosa, Y. Iwasa. ***Nature Phys. 9***, 563-569 (2013).

[3] H. T. Yuan, Z. K. Liu, G. Xu, S. F. Wu, D. Dumcenco, K. Yan, Y. Zhang, S. K. Mo, P. Dudin, V. Kandyba, M. Yablonskikh, A. Barinov, Z. X. Shen, S. C. Zhang, Y. S. Huang, X. D. Xu, Z. Hussain, H. Y. Hwang, Y. Cui, Y. L. Chen. ***Nano Lett. 16***, 4738-4745 (2016).

Figures

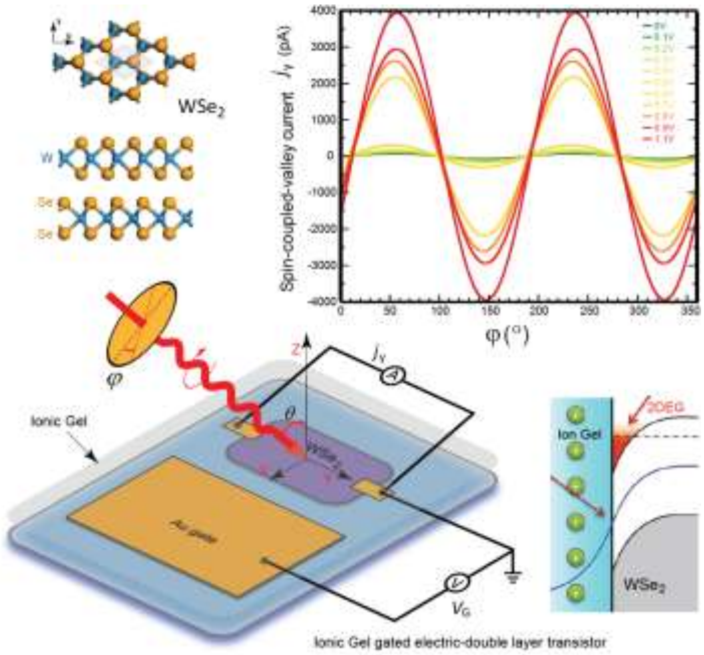

Figure 1: A spin- and valley-polarized photocurrent is generated in a WSe2 electric-double-layer transistor, with a direction and magnitude controlled by the degree of circular polarization of the incident radiation and by external electric field.