

Materials, Physics, and Functionalities of 2D Crystals

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Two-dimensional (2D) crystal of transition metal dichalcogenide (TMD) is attracting a significant interest as a beyond graphene material with a valley degree of freedom and spin-orbit interaction.

First, we report an experimental observation of the valley dependent Zeeman-type out-of-plane spin polarization using spin- and angle resolved-photoemission spectroscopy in MoS₂ [1], which is fully consistent with a theoretical prediction [2]. 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.

We also demonstrate FET related new functionalities, including gate-controlled Zeeman-type spin splitting [3], an ambipolar FET [4], and electric field induced superconductivity [5]. Finally, we demonstrate the electrically switchable chiral light source, an electro-optical conversion device [6].

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[2] D. Xiao et al., *Phys. Rev. Lett.* 108, 196802 (2012).

[3] H. T. Yuan et al., *Nat. Phys.* 9, 563 (2013).

[4] Y. J. Zhang et al., *Nano Lett.* 12, 1136 (2012), *ibid.* 13, 3023 (2013).

[5] J. T. Ye et al., *Science* 338, 1193 (2012).

[6] Y. J. Zhang et al., *Science* 344, 725 (2014).