Magnetic skyrmions in two-dimensional van der Waals heterostructures

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The field of skyrmion-electronics (called *skyrmionics*) has been actively investigated across a wide range of topics, inspired by the fascinating physical properties of magnetic skyrmions [1]. In this talk, I will present our recent experimental achievements on a new material platform for skyrmionics, two-dimensional (2D) van der Waals (vdW) materials and their heterostructures, where magnetic skyrmions and skyrmion lattices can be stabilized and readily manipulated using magnetic fields and electric current pulses.

Very recently, it has been reported that 2D vdW crystals can have long-range intrinsic ferromagnetism in few materials with strong magnetic anisotropy [2]. Due to the broken inversion symmetry and expected large spin-orbit coupling of vdW magnets, vdW magnets could permit the presence of Dzyaloshinskii-Moriya (DM) interaction that could stabilize magnetic skyrmions. In this talk, using both scanning transmission X-ray microscopy (STXM) and Lorentz transmission electron microscopy (Lorentz TEM) techniques, we experimentally present such demonstration of magnetic skyrmions and their crystal formation in ferromagnetic vdW crystals, Fe_3GeTe_2 (FGT), and FGT-based heterostructures. Using the exfoliated FGT-based heterostructure devices fabricated on a membrane substrate, we demonstrate the static and dynamic generation and manipulation of skyrmion crystal state (or skyrmion lattice, SkX), where either canted magnetic field or strong current pulse-induced thermal fluctuations transform magnetic domains into SkX. Our ab-initio calculation study using DFT further envisions the possible physical origins of DMI in vdW FGT-based heterostructures [3]. Together, we believe this work opens a door to 2D magnet-based chiral magnetism and skyrmionics.

[1] A. Fert *et al*., *Nat. Rev. Mater.* **2**, 17031 (2017)
[2] C. Gong *et al., Nature* **546**, 265-269 (2017); B. Huang *et al., Nature* **546**, 270-273
[3] T.-E. Park *et al., arXiv:190701425* (2019)

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