Tuning two-dimensional magnets with a twist

Samuel Mañas-Valero
C. Boix-Constant, C. Miranda-Pérez, E. Coronado
Instituto de Ciencia Molecular (ICMol), Universitat de València, Catedrático José Beltrán 2, Paterna, 46980 Spain.
Samuel.Manas@uv.es

The discovery of intrinsic magnetism in atomically thin van der Waals (vdW) materials has reshaped the understanding of low-dimensional spin physics and enabled new concepts for spin-based electronics. Unlike conventional thin-film magnets, vdW magnets allow atomic-scale control over thickness, stacking order, and interlayer coupling. Among these materials, CrSBr has emerged as a model system due to its strong in-plane anisotropy, air stability, and compatibility with heterostructure assembly.[1], [2]

CrSBr is a metamagnetic layered van der Waals (vdW) semiconductor (Fig. 1). The spins in every single layer (a–b plane) couple ferromagnetically between them ($T_c \approx 150$ K), pointing along the easy b axis, whereas the layers couple between them antiferromagnetically. By applying a magnetic field, it is possible to flip the layers' magnetization in a parallel fashion via a spin-flip (easy axis) and induce a spin reorientation (hard axis) along the magnetic field direction.[3]

Here, we fabricate vertical vdWs heterostructures based on untwisted and twisted monolayers and bilayers of CrSBr and inspect its magneto-transport (Fig. 1), revealing i) a spin-valve like behavior with negative magnetoresistance (MR) in the untwisted layers down to the bilayer case,[4] ii) positive MR for the pristine single layer,[4] iii) a multistep magnetization switching in orthogonally-twisted monolayer/monolayer heterostructures[5] and reaching iv) programmable magnetic hysteresis by combining orthogonally-twisted monolayers and bilayers of CrSBr.[6]

In summary, we demonstrate how magnetic anisotropy and interlayer coupling can be exploited to realize complex and highly tunable magnetic behavior in two-dimensional (2D) magnets.

References

[1] Phys. Rep. 1032, 1, 2023.
[2] Newton 1, 1, 100018, 2025.
[3] Small Science 4, 8, 2400244, 2024.
[4] Advanced Materials 34, 2204940, 2022.
[5] Nature Materials 23, 2, 212, 2024.
[6] Advanced Materials 37, 82415774, 2025.

Figures

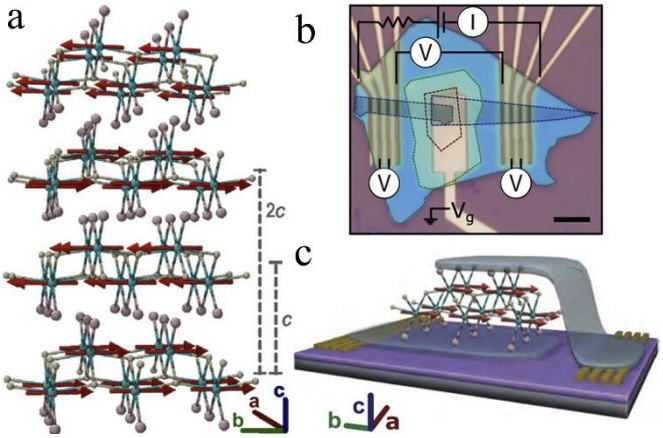

Figure 1: Magnetic van der Waals (vdW) heterostructures based on the vdW magnet CrSBr. a) Crystal structure. b-c) Vertical vdW heterostructure based on few-layers graphene and a single layer of CrSBr (device with the electrical transport configuration in b together with a sketch in c). Adapted from our works [3] and [4].

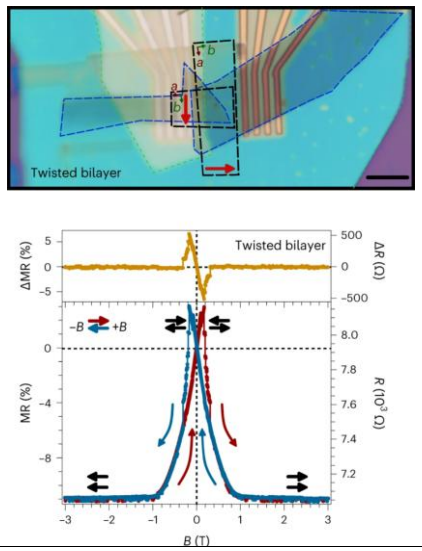

Figure 2: Emergence of magnetic hysteresis with multistep magnetization switching in orthogonally-twisted monolayer/monolayer CrSBr. Adapted from our work [5].