Probing the spin dimensionality in vertical van der Waals heterostructures based on CrSBr monolayer.

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Two-dimensional (2D) magnetic materials offer unprecedented opportunities both in terms of fundamental concepts and applied devices with special relevance in the fields of spintronics and magnonics.[1] Beyond the pioneering studies on CrI_3 and $Cr_2Ge_2Te_6$,[2,3] the family of 2D magnets has expanded to layered antiferromagnets with different spin anisotropies.[4–6] However, all these compounds are highly insulating, thus limiting their possibilities for being integrated into devices. Of particular interest is the case of the layered metamagnet CrSBr, a 2D semiconductor formed by ferromagnetic layers (Tc ~ 150 K) coupled antiferromagnetically between them. This material exhibits a rich physical scenario, including thermal spin dimensionality crossovers and low-temperature hidden order (T* ~ 40 K). Here, [7] we inspect the magneto-transport properties of monolayer, bilayer and trilayer CrSBr integrated into vertical van der Waals heterostructures (Figure 1). Our results in the monolayer limit demonstrate (1) the marked low dimensional character of the ferromagnetic layer, with short-range correlations extending at temperatures well above Tc, (2) a spin anisotropy, with the spins spontaneously aligned along the easy axis (b) of the plane, (3) a reorientation of these spins along a and c upon applying a moderate magnetic field in these directions, and (4) the appearance of field-induced phases in these two directions below ca. 30-40 K due to a cooperative freezing of the spins. In the multilayer case, a spin valve-like behavior is also observed characterized by a negative MR strongly enhanced below T*. Overall, the present results, supported by first-principles calculations, show that the monolayer and bilayer of CrSBr capture most of the physics present in the bulk, offering new insights into the physics of 2D magnets and the integration of these layers into vertical spintronic devices.

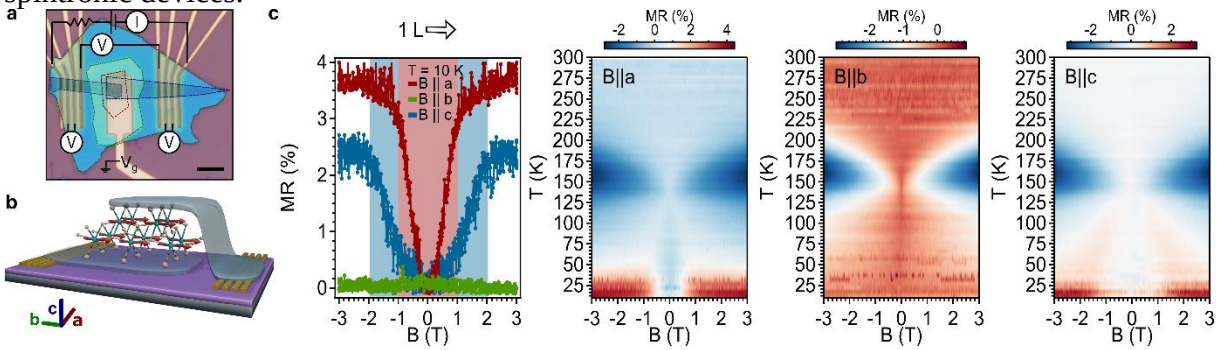

Fig. 1. Vertical van der Waals heterostructure based on CrSBr monolayer. a) Device image. Scale: 5 μm. b) Artistic view of device shown in a. c) Magneto-transport properties of the van der Waals heterostructure.

References

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