Universität Basel

Research Project

Revealing 2D magnetism via nanoscale magnetometry

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Project title Revealing 2D magnetism via nanoscale magnetometry
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Two-dimensional (2D) magnets have emerged as a new frontier in magnetism, both in terms of fundamental questions – including why such magnetism is stable at all – as well as from the device engineering point of view. In general, the stacking, twisting, and combining of van der Waals (vdW) materials with control down to individual atomic layers has started a revolution in heterostructure engineering. Layer-by-layer control offers a multitude of possible material combinations, without constraints imposed by lattice mismatch, along with the prospect of making compact devices, in which large electric fields can easily be applied. These new tools give researchers unprecedented control of interactions and band structure, as exemplified by the 2018 realization of superconducting twisted bilayer graphene.

In the realm of magnetism, these methods can be used to tune the magnetic properties of a material or even to make materials, which are non-magnetic in the bulk, magnetic in 2D. Most importantly, both in view of understanding the physics of 2D magnetism and exploiting it for applications, vdW engineering may allow us to realize new and useful magnetic phases, which are only possible in 2D.

In order to fully take advantage of these new developments, we must understand the role of anisotropy, disorder, inhomogeneity, and characteristic length-scales in 2D magnets and their heterostructures. Such investigations require sensitive local probes and techniques for measuring magnetism in small volumes. Our group, which has long worked at the forefront of sensitive magnetic imaging and torque magnetometry, is ideally positioned for such measurements.

Here, we propose to apply our unique and highly sensitive tools to three types of measurements in 2D magnets:

- **The characterization of static magnetism**: determining the magnetic state and its dependence on the number of layers, anisotropy, as well as the presence of spatially modulated states, domains, defects, and inhomogeneities.
- **The study of phase transitions and magnetic reversal**: measuring the stability of magnetic phases, the nature of phase transitions, the process of magnetic reversal, and the role of domains and inhomogeneity therein.
- **Understanding how to engineer 2D magnets**: observing the effects of stacking, twisting, and applying electric fields to controllably induce phase transitions, magnetic reversal, magnetic texture, or new magnetic phases.

The work of unravelling the mechanisms behind 2D magnetism is in its infancy. Given the inadequacy of conventional magnetic probes, we are convinced that our unique nanometer-scale magnetic field imaging and ultrasensitive torque magnetometry tools have much to contribute towards this effort. The results can be expected to have implications for 2D spintronic devices, 2D antiferromagnets, and the design of quantum materials via 2D vdW engineering in general.

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