Exploring Magnetism in the Nanoworld

Roland Wiesendanger
Institute of Applied Physics and Interdisciplinary Nanoscience Center Hamburg, University of Hamburg, D-20355 Hamburg, Germany
Email: wiesendanger@physnet.uni-hamburg.de

The developments of novel magnetic materials as well as spin-based electronics are hot topics of current research in nanoscale science. Both research fields profit tremendously from atomic-scale insight into magnetic properties and spin-dependent interactions at the atomic level. Based on the development of spin-polarized scanning tunneling microscopy (SP-STM) [1] we have recently established the novel method of single-atom magnetometry [2,3] which allows the measurement of magnetization curves and the determination of magnetic moments on an atom-by-atom basis. While the sensitivity level of single-atom magnetometry is below one Bohr magneton, it can easily be combined with the atomic-resolution imaging and manipulation capabilities of conventional STM, thereby offering a novel approach towards a rational material design based on the knowledge of the atomic-level properties and interactions within the solid state [4]. Moreover, an atom-by-atom design and realization of all-spin logic devices [5] has recently been demonstrated by our group based on the combined knowledge derived from surface physics, nanoscience, and magnetism.
By using SP-STM we have recently discovered nanoskyrmion lattices of single atomic layers of transition metals on particular substrates exhibiting a large spin-orbit coupling. In this case, skyrmionic lattices can be stabilized by Dzyaloshinskii-Moriya interactions combined with the breaking of inversion symmetry at surfaces and interfaces [6]. Following this approach, the existence of skyrmions of ultimate small size, being stable even in zero field, has recently been demonstrated, offering great potential for future nanospintronic devices.

[1] R. Wiesendanger, Rev. Mod. Phys. **81**, 1495 (2009).
[2] F. Meier et al., Science **320**, 82 (2008).
[3] L. Zhou et al., Nature Physics **6**, 187 (2010).
[4] A. A. Khajetoorians et al., Nature Physics **8**, 497 (2012).
[5] A. A. Khajetoorians et al., Science **332**, 1062 (2011).
[6] S. Heinze et al., Nature Physics **7**, 713 (2011).