Kolloquium

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Reaching the Ultimate Size Limit of a Magnet

physikalisches

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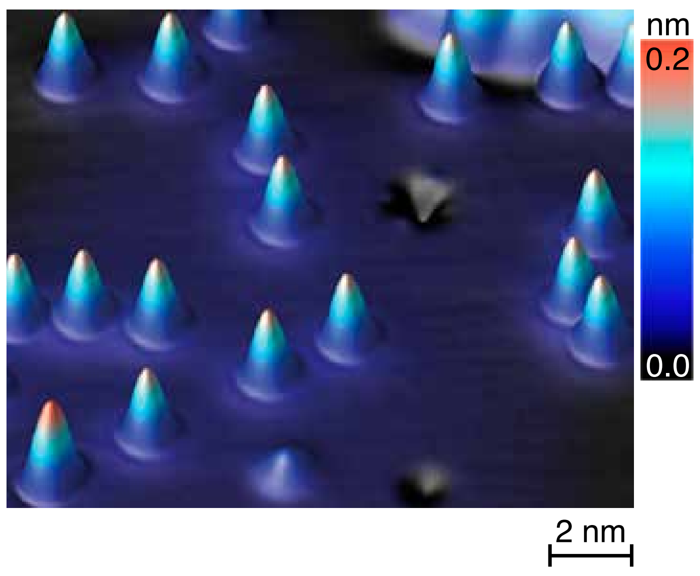
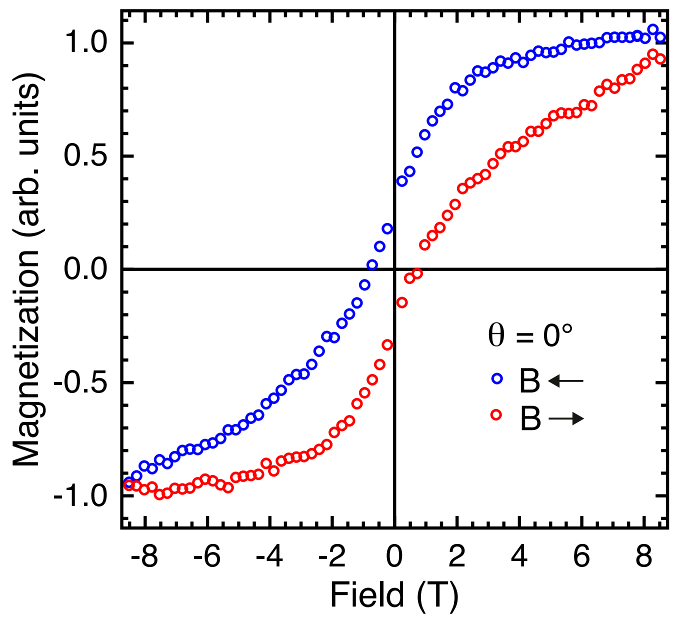
Ort: H34

Making magnets smaller increases thermal fluctuations of the magnetization direction, magnetization reversal by tunneling, or by scattering with conduction electrons. A magnet has by definition magnetic bi-stability, i.e., remanence and coercitivity. This requires the spin relaxation time (T_1) to be larger than the observation time, or larger than the timescale of interest for magnetic information storage. For magnetic quantum information processing, the relevant time is the coherence time (T_2) of the wavefunction describing the magnetic state.

We review the state of the art in molecular magnets and clusters assembled at surfaces. The smallest published magnets are Fe pentamers adsorbed on close-packed single crystal metal surfaces [1]. We show results where even trimers are stable and then focus on most recent experiments showing that even a single atom can exhibit remanent magnetization, thereby reaching the ultimate size limit of a magnet.

While former single atom studies have focussed on increasing the magnetic anisotropy energy, with Co on MgO(100) being the current record [2], the fact that all highly anisotropic single atom/surface systems are perfect paramagnets shows that magnetic anisotropy is only a necessary but not a sufficient condition for a stable single atom magnet. It is now known that the magnetic ground state and the crystal field symmetry have to be such that mixing of states with opposite magnetization is prohibited [3]. We show systems where this is the case, but underline the additional requirement of a tunnel barrier between metal substrate and magnetic atom that reduces magnetization reversal by electron scattering. We finally note that former claims of magnetic bi-stability in Ho atoms on Pt(111), derived from telegraph noise in the spin polarized STM current [4], are incompatible with the magnetic ground state determined by XMCD [5] and with more recent STM studies [6].





[1] A. A. Khajetoorians et al., Science 339, 55 (2013). [2] I. G. Rau et al., Science 344, 988 (2014). [3] C. Hübner et al., Phys. Rev. B 90, 155134 (2014). [4] T. Miyamachi et al., Nature 503, 243 (2013). [5] F. Donati et al., Phys. Rev. Lett. 113, 237201 (2014). [6] M. Steinbrecher et al., to be published (2015).