Observation and quantitative evaluation of superparamagnetic behavior utilizing magnetic exchange force microscopy and spectroscopy

Alexander Schwarz[1], Rene Schmidt, and Roland Wiesendanger[1]
[1]*Institute of Applied Physics,University of Hamburg, Jungiusstr. 11, 20355 Hamburg*
E-mail: aschwarz@physnet.uni-hamburg.de

Magnetic exchange force microscopy (MExFM) and spectroscopy (MExFS) can resolve magnetic surfaces and probe the distance dependence of the magnetic exchange interaction with atomic resolution [1,2]. Here we show that the distance dependence of the magnetic exchange interaction can be utilized to modify the barrier height between two magnetization directions in a well-controlled manner.
Contrast reversals observed with magnetically sensitive tips during MExFM imaging the antiferromagnetic Fe monolayer on W(001) show that tips can switch their magnetization direction by 180°, cf. Fig. 1. Since the magnetic exchange interaction is distance dependent, switching rate, lifetimes and the barrier height between the two states are distance dependent as well. Modeling the tip apex as superparamagnetic cluster with uniaxial anisotropy but otherwise independent of the rest of the tip, allows quantifying the energy barrier between both states as well as the zero field anisotropy. Moreover, the influence of a magnetic field via the additional Zeeman energy can be measured. Our study demonstrates the feasibility to observe dynamic magnetic processes utilizing magnetic exchange force microscopy and spectroscopy with atomic resolution.

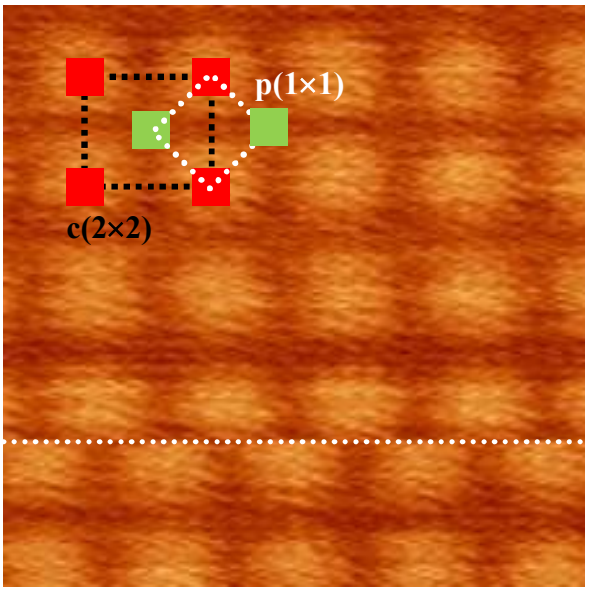

Fig. 1: MExFM image (2 nm × 2 nm) of the antiferromagnetic Fe monolayer on W(001). Structural p(1×1) and magnetic c(2×2) unit cell are indicated. Only one spin orientation is imaged as protrusion. The contrast reversal (dotted line) marks the reversal of the magnetization direction at the tip apex.

References:

[1] U. Kaiser, A. Schwarz, and R. Wiesendanger, Nature **446**, 522 (2007).
[2] R. Schmidt, A. Schwarz, and R. Wiesendanger, Phys. Rev. Lett. **106**, 257202 (2011).