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Nanosecond Scanning Tunneling Microscopy: resolving spin dynamics at the atomic scale

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With the advent of nanoelectronics, functional electronic elements advance towards atomic dimensions and analysis techniques need to keep pace. Scanning tunneling microscopes (STM) have evolved into standard tools to measure the static electronic properties of nanostructures, molecules and atoms. Here we show how the STM can be used to access the equally important dynamical properties on time scales ranging from pico- to nanoseconds. We combine inelastic electron tunneling spectroscopy (IETS) with an all-electronic pump-probe measurement scheme and record the dynamical evolution of magnetic atoms on surfaces in the time domain [1]. We focus on the dynamics of electron spin relaxation in transition metal atoms placed onto a copper nitride decoupling layer on Cu(100). On this surface Fe atoms experience large magneto-crystalline anisotropy [2] that enables long spin lifetimes. At the same time the quantum mechanical nature of the discrete spin states allows for an additional path of spin relaxation: quantum tunneling of magnetization. We probe the dynamic behavior associated with this process and find that placing a Cu atom close to a Fe atom boosts the uniaxial anisotropy energy and creates a long-lived spin state with relaxation times in excess of 200 ns. The ability to probe individual nanostructures with atomic spatial and nanosecond temporal resolution opens a new avenue to explore spin dynamics and other dynamical phenomena on the intrinsic length scale of the underlying interactions.

[1] S. Loth, M. Etzkorn, C. P. Lutz, D. M. Eigler, A. J. Heinrich, Science 329 1628 (2010).
[2] C.F. Hirjibehedin, et al., Science 317, 1199 (2007).