MA 62: Magnetic Imaging

Time: Friday 10:45–12:00 Location: HSZ 04

MA 62.1 Fri 10:45 HSZ 04

Observation of superparamagnetism in image potential states using SP-STM — •Anika Schlenhoff, Andreas Sonntag, Stefan Krause, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg

Several eV above their Fermi energy ferromagnets exhibit image potential states (IPS) which are located nanometers above the surface in the vacuum. As these states are spin-split, their magnetization can be imaged by spin-polarized scanning tunneling microscopy (SP-STM) [1]. Due to the great tip-sample distance, the risk for destructive mechanical contact is minimized. Whereas magnetic IPS have been extensively studied by laterally averaging methods [2], only recently first SP-STM experiments on IPS were performed on *bulk-like* Fe/W(110) [1]. It is an open question wether magnetic IPS are also observable above atomic-scale, only one atomic layer high magnets. Therefore, we investigate IPS above Fe/W(110) monolayer islands consisting only of about 100 atoms. These nanoislands exhibit a monodomain magnetization state and thermally switch their magnetization at 40 K [3]. In our SP-STM experiments, this switching behavior is recorded within the IPS, thereby demonstrating that the exchange splitting of IPS is observable even above atomic-scale magnetic nanostructures. Influences of the increased bias voltage on the thermal switching behavior will be discussed.

[1] A. Kubetzka *et al.*, Appl. Phys. Lett. **91**, 012508 (2007).
[2] M. Donath *et al.*, Surf. Sci. **601**, 5701 (2007).
[3] S. Krause *et al.*, Phys. Rev. Lett. **103**, 127202 (2009).

MA 62.2 Fri 11:00 HSZ 04

Quantification of spin torque and Joule heating using SP-STM — •Stefan Krause, Gabriela Herzog, Anika Schlenhoff, Andreas Sonntag, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg

Spin-polarized scanning tunneling microscopy (SP-STM) is a powerful tool not only to image but also to manipulate magnetic nanostructures at ultimate lateral resolution. Using a high spin-polarized current originating from a magnetic tip the thermal magnetization switching behavior of an individual Fe/W(110) monolayer nanoisland with uniaxial anisotropy is influenced: Whereas Joule heating increases the switching frequency, the spin torque lifts the degeneracy of the two magnetic state lifetimes, forcing the island to favor one magnetic orientation.[1,2]

In general, the microscopic details of spin torque and Joule heating are still to be discovered. The capability of SP-STM to inject a high tunnel current into an individual nanoisland and simultaneously monitor its magnetic state allows for a direct quantification of spin torque and Joule heating from the observed switching behavior. The results are discussed in terms of current-dependent state lifetimes and interpreted as the modification of the switching energy barrier due to spin torque and an increased temperature of the nanoisland due to Joule heating.

[1] S. Krause *et al.*, Science **317**, 1537 (2007).
[2] G. Herzog, S. Krause and R. Wiesendanger, Appl. Phys. Lett. **96**, 102505 (2010).

MA 62.3 Fri 11:15 HSZ 04

Morphological, electronic and magnetic characterization of bulk Cr tips — •Marco Corbetta[1], Safia Ouazi[1], Fabio Donati[1,2], Yasmine Nahas[1], Hirofumi Oka[1], Sebastian Wedekind[1], Dirk Sander[1], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [2]CNISM, NEMAS and Dipartimento di Energia - Politecnico di Milano, Milano, Italy

The most delicate task for successful SP-STM measurements is the preparation of suitable tips offering high spatial resolution, high spin polarization and negligible magnetic stray field. Nonmagnetic tips covered with an ultrathin film of antiferromagnetic material as Cr have been largely and successfully used [1]. The main drawback of coated tips is that an in-situ preparation is required. Recently a simple and reliable method for the preparation of bulk Cr tips using only a standard electrochemical etching has been proposed [2]. We produced and used such tips for in-field spin-polarized STM measurements at 7 K on Co nano-islands on Cu(111). We obtain stable and reliable spin-resolved imaging and spectroscopy results. We measure symmetric hysteresis loops of the differential conductance, which show that the magnetization direction of the Cr tip apex follows the external magnetic field direction. Measuring dI/dV asymmetry curves on Co islands we find that the spin polarization of bulk Cr tips can be as large as 30%, which is larger as compared to Cr/Co/W tips [3]. [1] A. Kubetzka et al., Phys. Rev. Lett. 88, 057201 (2002). [2] A. Li Bassi et al., Appl. Phys. Lett. 91, 173120 (2007). [3] H. Oka et al., Science 327, 843 (2010).

MA 62.4 Fri 11:30 HSZ 04

Contrast formation and deconvolution of pinned UCS by MFM — •Sevil Ozer[1], Niraj Joshi[1], Hans Josef Hug[1,2], Miguel Marioni[2], and Sara Romer[2] — [1]Department of Physics, University of Basel, CH-4056 Basel, Switzerland — [2]EMPA, CH-8600 Dubendorf, Switzerland

In prior work we presented MFM images of pinned, uncompensated spins (UCS) at the antiferromagnet/ferromagnet (AF/F) interfaces in exchange-biased systems[1,2,3]. We argued that the MFM image obtained after saturation of the F arises from the pinned UCS. Here a detailed analysis of the different contributions to the measured MFM contrast is presented. To deconvolute the various contrast contributions, their behavior upon field reversal was studied. Our analysis reveals that the topography-induced variations of the vdW forces, the magnetic field mediated forces generated by variations in the F-layer thickness, roughness and saturation magnetization and those from the rotating UCS do NOT change sign upon field reversal. The contrast arising from the pinned UCS reverses, because the magnetization of the tip has flipped. After calibration of the imaging properties of the MFM tip by using the MFM data of F-domain image, the areal density of the pinned UCS can be devonvolved from the frequency shift MFM data of the pinned UCS.

[1] P. Kappenberger et al., Phys. Rev. Lett, 91 (2003) 267202
[2] I. Schmid et al., Europhys. Lett., 81 (2008) 17001
[3] I. Schmid et al., Phys. Rev. Lett., 105 (2010) 197201

MA 62.5 Fri 11:45 HSZ 04

A combined Laser-scanning / Wide-field Kerr Microscope to Investigate the Switching Behavior of Nanomagnetic Logic Devices — •Stephan Breitkreutz, Josef Kiermaier, Benedikt Neumeier, Markus Becherer, and Doris Schmitt-Landsiedel — Lehrstuhl für Technische Elektronik, TU München

Nanomagnetic Logic (NML) is a promising candidate for future computing devices with inherent logic and memory function in every single device. In order to observe and develop NML, fast and high-resolution measurement techniques are required.

Based on the polar magneto-optical Kerr effect (p-MOKE) we developed a scanning microscope combining two different mode to characterize single nanomagnets and record high-resolution images of magnetic samples. In laser-scanning mode the sample is scanned with a blue laser achieving a resolution down to 400 nm. This allows to measure hysteresis curves of single nanomagnets and high-resolution images of dot configurations. The setup provides field sweeping rates of 10 T/s and time resolved observation of switching events in the 10-μs-range. In wide-field mode the sample is illuminated by homogeneous, highly polarized LED light and analyzed with a 1280·1024 pixel CMOS-camera with 27 frames/s. This allows for fast image analysis of large arrays of nanomagnets e.g. to observe dot interactions due to coupling and signal propagation in nanomagnetic gates.

Performed measurements demonstrate the versatility of the combined measurement mode for development and optimization of NML devices.