Plenary Talk PV XI Fri 8:30 HSZ 01

Spin Mapping and Spin Manipulation on the Atomic Scale

— •Roland Wiesendanger — Institute of Applied Physics and Interdisciplinary Nanoscience Center Hamburg, University of Hamburg, D-20355 Hamburg, Germany

A fundamental understanding of magnetic phenomena requires the determination of spin structures and spin excitations down to the atomic scale. The direct visualization of atomic-scale spin structures [1-4] has first been accomplished by combining the atomic resolution capability of Scanning Tunnelling Microscopy (STM) with spin sensitivity, based on vacuum tunnelling of spin-polarized electrons [5]. The resulting technique, Spin-Polarized Scanning Tunnelling Microscopy (SP-STM), nowadays provides unprecedented insight into collinear and non-collinear spin structures at surfaces of magnetic nanostructures and has already led to the discovery of new types of magnetic order at the nanoscale [6,7]. More recently, the development of subkelvin SP-STM has allowed studies of magnetic properties of individual magnetic adatoms on non-magnetic substrates as well as the magnetic interactions between them [8]. Based on SP-STM experiments performed at temperatures of 300 mK, indirect magnetic exchange interactions at the sub-milli-electronvolt energy scale between individual paramagnetic adatoms as well as between adatoms and nearby magnetic nanostructures could directly be revealed in real space up to distances of several nanometers. In both cases we have observed an oscillatory behavior of the magnetic exchange coupling, alternating between ferromagnetic and antiferromagnetic, as a function of distance. Moreover, the detection of spin-dependent exchange and correlation forces has allowed a first direct real-space observation of spin structures at surfaces of antiferromagnetic insulators [9]. This new type of scanning probe microscopy, called Magnetic Exchange Force Microscopy (MExFM), offers a powerful tool to investigate different types of spin-spin interactions based on direct-, super-, or RKKY-type exchange down to the atomic level. Finally, the combination of spin state read-out and spin state manipulation, based on spin-current induced switching across a vacuum gap by means of SP-STM [10], provides a fascinating novel type of approach towards ultra-high density magnetic recording without the use of magnetic stray fields.

[1] R. Wiesendanger, I. V. Shvets, D. Bürgler, G. Tarrach, H.-J. Güntherodt, J. M. D. Coey, and S. Gräser, Science **255**, 583 (1992)
[2] S. Heinze, M. Bode, O. Pietzsch, A. Kubetzka, X. Nie, S. Blügel, and R. Wiesendanger, Science **288**, 1805 (2000)
[3] A. Kubetzka, P. Ferriani, M. Bode, S. Heinze, G. Bihlmayer, K. von Bergmann, O. Pietzsch, S. Blügel, and R. Wiesendanger, Phys. Rev. Lett. **94**, 087204 (2005)
[4] M. Bode, E. Y. Vedmedenko, K. von Bergmann, A. Kubetzka, P. Ferriani, S. Heinze, and R. Wiesendanger, Nature Materials **5**, 477 (2006)
[5] R. Wiesendanger, H.-J. Güntherodt, G. Güntherodt, R. J. Gambino, and R. Ruf, Phys. Rev. Lett. **65**, 247 (1990)
[6] K. von Bergmann, S. Heinze, M. Bode, E. Y. Vedmedenko, G. Bihlmayer, S. Blügel, and R. Wiesendanger, Phys. Rev. Lett. **96**, 167203 (2006)
[7] M. Bode, M. Heide, K. von Bergmann, P. Ferriani, S. Heinze, G. Bihlmayer, A. Kubetzka, O. Pietzsch, S. Blügel, and R. Wiesendanger, Nature **447**, 190 (2007)
[8] F. Meier, L. Zhou, J. Wiebe, and R. Wiesendanger, Science **320**, 82 (2008)
[9] U. Kaiser, A. Schwarz, and R. Wiesendanger, Nature **446**, 522 (2007)
[10] S. Krause, L. Berbil-Bautista, G. Herzog, M. Bode, and R. Wiesendanger, Science **317**, 1537 (2007)