Carnegie Mellon
Materials Science and Engineering Seminar Series

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"Imaging magnetic nanostructures with atomic spin resolution"

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10 A.M. Seminar in Baker Hall 136A

Within the recent years spin-polarized scanning tunneling microscopy (SP-STM) has become a mature tool for high spatial resolution studies of spin structures down to the atomic scale. Together with its high surface sensitivity this makes SP-STM particularly suited for the investigation of complex antiferromagnetic or superparamagnetic surfaces which— because of the lack of macroscopic magnetization—could only be studied in some rare cases with very moderate spatial resolution in the past.

One particularly graphic example is the two-dimensional atomic-scale antiferromagnetic (AFM) structure observed within a Mn monolayer on tungsten (110) [1]. On the atomic scale SP-STM data reveal periodic stripes running along the [001] direction with an inter-stripe distance of 0:47 ± 0.03 nm, indicating row-wise AFM order. Large scale images reveal, however, that the magnetic amplitude is not constant but is modulated with a period of about 12 nm. Magnetic field-dependent experiments show that this modulation is caused by an AFM spin spiral. First-principles calculations identify a cycloidal spin spiral which is caused by the Dzyaloshinskii-Moriya (DM) interaction as the driving mechanism for this complex magnetic order. Due to thermal excitations this spin structure becomes unstable in nano-scale islands.

Switching the magnetization of a magnetic bit by injection of a spin-polarized current offers the possibility for the development of innovative high-density data storage technologies. We show how individual superparamagnetic iron nanoislands with typical sizes of 100 atoms can be addressed and locally switched using a magnetic scanning probe tip, thus demonstrating current-induced magnetization reversal across a vacuum barrier combined with the ultimate resolution of spin-polarized scanning tunneling microscopy [2]. Our technique allows us to separate and quantify three fundamental contributions involved in magnetization switching (i.e., current-induced spin torque, heating the island by the tunneling current, and Oersted field effects), thereby providing an improved understanding of the switching mechanism.

Matthias Bode received the diploma in physics from FU Berlin, Germany, in 1993, and a Ph.D. degree in physics from the University of Hamburg, Germany, in 1996. Based on his works on spin-polarized scanning tunneling microscopy, a magnetic imaging technique with a resolution down to the atomic limit, he received the habilitation in experimental physics from the University of Hamburg, Germany, in 2003. Since 2007 Matthias Bode is Group Leader at the Center for Nanoscale Materials at Argonne National Laboratory, Illinois. His research field is the exploration of correlations between structural, electronic, and magnetic properties of epitaxial nanostructures with the special interest on frustrated antiferromagnetic surfaces, superparamagnetism, and new spin-orbit-driven magnetic phenomena. Dr. Bode has published more than one hundred peer-reviewed articles, three review articles, and three book chapters. He was awarded with the Philip-Morris-Award for research in 2003 and was Distinguished Lecturer of the IEEE Magnetics Society in 2007.