Stony Brook University
The Graduate School

Doctoral Defense Announcement

Abstract

Understanding Nanoscale Magnetization Reversal and Spin Dynamics by Using Advanced Transmission Electron Microscopy

By

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In the forefront of spintronics research, transmission electron microscopy (TEM) is not only an essential tool for examining matter with high spatial resolution, but also associated with it is a rich variety of in-situ capabilities making quantitative investigation of the intriguing microscopic magnetic phenomena possible. This dissertation covers TEM studies of nanoscale magnetization reversal and high frequency spin dynamics of patterned magnetic elements, which hold great promise for the development of next generation recording/memory technologies.

We first focus on the static spin configurations and magnetization reversal processes of patterned soft magnetic thin films. Using in-situ Lorentz microscopy and off-axis electron holography, we find patterning the same magnetic material with different geometries can create sharply distinct domain structures and switching properties, which can be effectively explained by shape anisotropy and interlayer stray field coupling. We then exploit these effects by designing shape-engineered tri-layer nanomagnets, of which the magnetization reversal process can be precisely controlled to achieve specific remanent states.

We also study the magnetic behavior of nanomagnets in the high frequency regime, where spin torque transfer between current and magnetization represents a radically new data-writing concept. Here, we design and construct a novel TEM stage to apply microwave excitation stimulus to the patterned nanomagets, and directly observe the current-induced resonant precession of the vortex core with unprecedented spatial resolution. We measure the precession orbits as a function of both frequency and current density, and succeed in quantifying the resonant frequency and damping coefficient. For the first time we obtain experimental proof that the vortex precession orbit is elliptical when it's off-resonance, with nanometer resolution.

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