MAR07-2006-002942
Abstract for an Invited Paper
for the MAR07 Meeting of
the American Physical Society

Ferromagnetic resonance of individual nanomagnets driven by spin-polarized currents.

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Spin-polarized electrons passing through a nanoscale magnet can transfer their spin angular momentum to the magnetization, applying a torque far more efficiently than can be achieved by employing magnetic fields. We discuss the characterization of microwave-frequency magnetic excitations driven by these spin-transfer torques in metallic spin-valve devices and magnetic tunnel junctions using high-bandwidth electrical techniques. We first describe spontaneous magnetic oscillations that can be excited by DC currents, and then focus on a new form of ferromagnetic resonance (FMR) that uses high-frequency spin-polarized currents to excite resonance, instead of high-frequency magnetic fields. This technique allows measurements of individual magnetic samples orders of magnitude smaller than can be probed by traditional FMR, and should scale to much smaller devices as well. Using spin-transfer-driven FMR, we have been able to measure the spectra of normal modes for individual nanomagnets, including both the fundamental mode and higher-order more spatially-nonuniform modes. From the lineshapes, we can distinguish two different resonant regimes: simple FMR and phase-locking to a pre-existing DC-driven mode. The linewidths also enable efficient measurements of the magnetic damping parameter in single nanomagnets. We find that the FMR lineshapes differ between metallic spin valves and magnetic tunnel junctions when a DC current is applied, pointing to important differences in the fundamental mechanisms of the spin transfer torque in these two systems. This work was done in collaboration with P. M. Braganca, A. G. F. Garcia, I. N. Krivorotov, J. Z. Sun, J. C. Slonczewski, R. A. Buhrman, and D.C. Ralph.