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Magnetodynamics of spin torque switching in nanometer sized magnetic devices

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Since the theoretical predictions of by Berger and Slonczewski in 1996, spin-transfer dynamics in spin valves and tunnel junctions have been of great interest for the development of magnetic RAM, spin-torque nano-oscillators, and spin diodes. Spin transfer devices use spin polarized currents flowing through a nanoscale magnetic structure to induce torques on the local moments, causing a change in the direction of magnetization of the film. The magnetization can be switched more efficiently using spin transfer than through the use of magnetic fields and unique dynamical magnetization states can be stabilized. In order to understand the magnetization dynamics and the switching behaviors in nanoscale magnetic devices, it is important to characterize their normal modes of oscillation, thermal fluctuations, and the statistical switching current distributions. In conventional field switching, the switching event evolves from a normal mode whose frequency is driven to zero. Spin torque switching, in contrast, evolves from a mode whose linewidth is driven to zero. Nanoscale devices have many active magnetization modes each with different spatial distributions, frequencies, and effective activation volumes. Depending of the device shape and the profile of the excitation pulse different modes can contribute to the switching process. In this talk we describe our measurements of spin torque induced magnetization dynamics and switching in nanometer scale magnetic spin valves and MgO tunnel junctions. Switching probabilities were measured for pulses with durations from 0.1 ns up to 1 s and correlated with device level ferromagnetic resonance (FMR). Thermal and spin torque FMR data show complex spectra and evolution of the modes with applied fields and currents. The nanoscale FMR spectra can highlight device-to-device variations, be used to identify the modes important in the switching process, and measure the mode damping that determines the critical currents for switching.