Magnetic Interfaces and Nanostructures
Room 316 - Session MI-WeM

Current-Induced Magnetic Switching and Excitations

Moderator: S.E. Russek, National Institute of Standards and Technology

8:20am **MI-WeM1 Direct Measurements of Spin Momentum Transfer Induced Dynamics***, **W.H. Rippard**, M.R. Pufall, S. Kaka, S.E. Russek, T.J. Silva,* National Institute of Standards and Technology

Slonczewski and Berger first predicted that the angular momentum from a spin-polarized current can be transferred to a ferromagnetic film creating a torque on the film magnetization, the so-called spin momentum transfer (SMT) effect. Previous work has shown that for sufficiently high current densities and applied magnetic fields, there occurs an abrupt increase in the dc resistance of point contact junctions or nanopillar devices. In accordance with theoretical predictions, these steps have been attributed to the onset of coherent magnetization dynamics. We will discuss our recent results from studying these excitations directly in a number of different materials, sample geometries, and applied field geometries. In general we find that the excitations can be well described with the Kittel equation for magnetization dynamics. We commonly observe these excitations from frequencies below 5 GHz to greater the 25 GHz. We have found that these linewidths are often as narrow as 20 MHz and persist for fields from H = 200 Oe to ~1 T, although the specifics depend on the particular geometry and material of the device under study. We also compare these results to single-domain model simulations of SMT induced dynamics and find good agreement between the simulated and measured behavior.

8:40am **MI-WeM2 Dynamical Modes of Nanomagnets Driven by a Spin-Polarized Current***, S.I. Kiselev, **J.C. Sankey**, I.N. Krivorotov, N.C. Emley,* Cornell University*; S.E. Russek,* National Institute of Standards and Technology*; R.J. Schoelkopf,* Yale University*; R.A. Buhrman, D.C. Ralph,* Cornell University

A spin-polarized current can apply a torque directly to a ferromagnet through transfer of angular momentum. Here we report direct electrical measurements of microwave-frequency magnetic dynamics driven by DC spin-transfer currents in Co/Cu/Co nanopillar structures. We demonstrate that spin-transfer can produce several types of excitations, including small angle elliptical precession, more complicated large angle motions and high current static state. Microwave power emitted by magnetic multilayer devices may enable nanoscale oscillators and microwave sources generated by DC current.

9:00am **MI-WeM3 Current-Induced Precession at Ferromagnetic Interfaces***, **A. Zangwill**,* Georgia Institute of Technology **INVITED**

It is well established experimentally that the relative orientation of two ferromagnetic layers in a multilayer film can be switched by passing a sufficiently large current through the film. Often, this "converse GMR" effect is preceded by a precession-type instability of one or both ferromagnetic layers. The signature of this instabilty has also been seen during point contact current injection into a single ferromagnetic film. In this talk, I discuss the precessional phenomenon theoretically using a combination of phenomenological modelling, Boltzmann transport theory, and first-principles quantum mechanical calculations. The key ingredient is a "spin-transfer" torque associated with spin polarization of the electric current. Special emphasis is placed on the possibility of quantitative comparison with experiment.

9:40am **MI-WeM5 Spin-transfer Induced Magnetic Switching in Batch-fabricated sub-100 nm Spin-valves***, **J.Z. Sun**,* IBM T.J. Watson Research Center*; T.S. Kuan,* SUNY at Albany*; M.J. Rooks,* IBM T.J. Watson Research Center*; J.M.E. Harper,* IBM T.J. Watson Research Center and University of New Hampshire*; R.A. Carruthers, S.M. Rossnagel, R.H. Koch,* IBM T.J. Watson Research Center **INVITED**

A hard-mask stencil method is developed for the efficient fabrication of sub-100nm current-perpendicular spin-valve junctions with low contact resistance. The approach uses a trilayer template. The templated substrate is batch fabricated first with the junction features defined by a top stencil layer and an undercut in the insulator. The spin-valve thin film stack is deposited afterwards into the stencil, with the insulator undercut providing the necessary isolation of magnetic exchange coupling. By placing electron-beam lithography at the very beginning of the process before the deposition of the magnetic thin films, this approach improves the turnaround time for materials optimization in nanostructures. Using this approach, spin-transfer induced magnetic switching and magnetic excitation are observed for junctions down to 50nm x 100nm in size.

10:20am **MI-WeM7 Current-Driven Magnetization Reversal at High Magnetic Fields in Co/Cu/Co Nanopillars***, **B. Oezyilmaz**[1], A.D. Kent,* New York University*; D. Monsma,* Harvard University*; J.Z. Sun, M.J. Rooks, R.H. Koch,* IBM T.J. Watson Research Center

Recently there has been great interest in current induced angular momentum transfer in magnetic nanostructures. Its observation in point contact experiments on magnetic multilayers in the field perpendicular geometry has boosted efforts to understand the underlying mechanism.@footnote 1@ We have studied spin transfer torques in the same field perpendicular configuration in sub-micron size (~100 nm) Co/Cu/Co pillar devices at 4.2 K and 293 K. Pillars have been fabricated by means of a new nano-stencil mask process, which enables the production of large arrays of templates ideal for systematic variations of layer thicknesses and compositions. I(V) measurements in large magnetic fields (>1.5T) show an abrupt increase in device resistance at high current densities for one current polarity. The onset of this transition is marked by both a hysteretic step in the DC voltage and a hysteretic peak in dV/dI. The magnitude of the step in resistance is similar to the device in-plane GMR (~5 %) and is thus consistent with current-induced switching into a high resistance state of anti-parallel magnetization in large applied perpendicular magnetic fields. In contrast to experiments with point-contacts, our results suggest that the peak in dV/dI marks the end and not the onset of magnetization dynamics.@footnote 2@ High field hysteresis in MR measurements at fixed (positive) bias current is also observed which is consistent with this interpretation. Micromagnetic modeling that includes a spin-transfer torque is in qualitative agreement with these observations and provides an explanation for the basic features observed in the device I-V characteristics as a function of magnetic field. Further, to study the importance of the longitudinal spin-accumulation, pillars with only a single Co layer have been fabricated. Initial experiments with these Cu/Co/Cu sub-micron size pillar devices will be discussed. @FootnoteText@@footnote 1@M. Tsoi et al, Nature 406, 46 (2000). @footnote 2@B. Oezyilmaz et al., arXiv:cond-mat/0301324.

10:40am **MI-WeM8 Current-Triggered Domain Wall Motion in Focused Ion Beam Fabricated Magnetic Nanowires***, **C.T. Rettner**, M. Tsoi, L. Thomas, S. Parkin,* IBM Almaden Research Center

Focused ion beam techniques have been used to pattern NiFe and CoFe thin films into nano-wires to study magnetic domain wall motion triggered by an electric current. We have investigated a variety of shapes, including simple and notched straight lines as well as zigzags and semi-circular shapes. Our scheme begins with a large structure created by deposition of the magnetic material onto SiO2 through a shadow mask. This structure consists of 1 mm pads connected by a 0.1 mm line. The focused ion beam is first used to cut this line with a 11 nA beam leaving just 6 microns of film on the centerline. Next an 11 pA beam is used to roughly form the desired shape in this region, and a 4 pA with ~25 nm resolution is used to add details such as notches and to form the final dimensions. We will discuss our observations of current-triggered domain-wall motion in these structures, including results for motion in zero fields. These results include magneto-resistive measurements and MFM imaging. Finally, we will briefly discuss the results in terms of micro-magnetic simulations for these structures.

[1] **Falicov Student Award Finalist**

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