Condensed Matter Physics Institute Seminar

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Conductive Atomic Force Microscopy of Magnetic Tunnel Junctions and Nanoparticles

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Magnetic tunnel junctions (MTJs) with thin CoFeB layers and perpendicular anisotropy can be switched at much lower current densities (~10^2 A/cm^2) than those with thicker layers, in-plane anisotropy, and spin transfer torque reversal (~10^6 A/cm^2). The perpendicular anisotropy arises from the CoFeB/MgO interface and its magnitude depends on the applied voltage. Low power MTJs would be more compatible with existing CMOS transistors, provided the magnetic devices can be scaled to small sizes.

Here we describe the fabrication of MTJs ranging from 18 to 500 nm and characterization of their switching as a function of magnetic field and voltage bias. Conductive atomic force microscopy (C-AFM) enables scanning magnetoresistance measurements of individual MTJs. Major and minor hysteresis loops were collected as a function of the applied magnetic field to determine the effective anisotropy of the free layer. When the free layer was metastable, the tunnel current showed random telegraph noise. Surprisingly, the magnetization reversal mechanism differs, depending on whether the initial state of the MTJ is parallel or antiparallel. Voltage induced switching of the free layer was observed in devices larger than 60 nm. The regimes of magnetization reversal by coherent rotation and domain wall nucleation are discussed, along with the prospects of extending the range to smaller low power devices.

The dynamics of individual magnetic nanoparticles can also be determined from C-AFM. Here the nanoparticles are deposited on a magnetic thin film, and a relatively isolated from one another. When the particles are superparamagnetic, so that the direction of their magnetic moment changes in time due to thermal fluctuations, there is telegraph noise in the magnetoresistance. The signal is analyzed in terms of models of monodomain nanoparticles.