Magnetic Thin Films with Graded or Tilted Anisotropy for Spintronic Devices

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ABSTRACT

In this thesis magnetic thin films with graded or tilted anisotropy are intensively studied for potential applications in spintronic devices.

A continuum of stable remanent resistance states is realized in Co/Pd multilayers based on a perpendicularly magnetized pseudo spin valve (PSV). The Co/Pd multilayers have been deposited using magnetron sputtering. By varying the Co thickness in each repeating unit, a graded anisotropy through the multilayer is achieved. We then incorporate this graded Co/Pd multilayer into a PSV as the free layer. The remanent resistance states are systematically adjustable depending on the reversal field. The gradual reversal of the free layer with applied field and the field-independent fixed layer leads to a range of stable and reproducible remanent resistance values, as determined by the giant magnetoresistance of the device. An analysis of first-order reversal curves (FORCs) combined with magnetic force microscopy (MFM) shows that the origin of the effect is the field-dependent population of up and down domains in the free layer. Thus, these structures have great potential for applications such as field-tunable resistance trimming devices, memristive devices, or magnetic analog memories with a continuous number of states per memory cell, thereby allowing much higher information storage.

We have also successfully realized FePtCu thin films with graded anisotropy. During deposition a compositional gradient is achieved by continuously varying the Cu content from the top to bottom. After annealing at a proper temperature, the top Cu-poor regions remain in the as-deposited soft A1 phase, while the bottom Cu-rich regions transform into hard $L1_0$ phase. Hence the gradient anisotropy is established through the film thickness. The critical role of the annealing temperatures (T_A) on the resultant anisotropy gradient is investigated. Magnetic measurements support the creation of an anisotropy gradient in properly annealed films which exhibit both a reduced coercivity and moderate thermal stability. The reversal mechanism of graded anisotropy has been investigated by alternating gradient magnetometer (AGM) and magneto optical Kerr effect (MOKE) measurements in combination with the FORC technique. The AGM-FORC analysis clearly shows the soft and hard phases. MOKE-FORC measurement, which preferentially probes the surface of the film, reveals that the soft components are indeed located toward the top surface. We provide a detailed study of the how the anisotropy gradient in a compositional graded FePtCu film gradually develops as a function of the T_A. By utilizing the in-situ annealing and magnetic characterization capability of a physical property measurement system (PPMS), the evolution of the induced anisotropy gradient is elucidated. These results are important and useful for the solving the magnetic ‘‘trilemma’’ of magnetic recording technology.

The Co/Pd-NiFe exchange spring system is investigated. Due to the competition between the strong perpendicular anisotropy of the Co/Pd multilayer and the in-plane shape anisotropy of the NiFe, the magnetization in the NiFe tilts out of the film plane. Experimental data from conventional magnetometry, and MFM, along with one-dimensional simulations, show that the titling angle in the NiFe layer is highly tunable from 0 to 60° by simply changing the thickness of NiFe. We employed the Co/Pd-NiFe exchange spring system with appropriate NiFe thickness as the polarizer in nano-contact spin torque oscillators (STOs) which show vortex oscillations at low fields.

Keywords: Spintronic, magnetic thin films, graded anisotropy, tilted anisotropy, field-tunable resistance, spin torque oscillators.