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Study of magnetization reversal in perpendicularly magnetized TbCo based spin-valves

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The study of domain wall propagation in magnetic material showing PMA (Perpendicular Magnetic Anisotropy) and zero magnetization is particularly interesting for technological applications as well as fundamental understanding. Some theory [1] predicts that the critical polarized current needed to induce domain wall propagation in such system is small. This reduction of the critical current has never been observed and would be of prime importance for data storage application such as race track memories [2]. The materials that have been chosen are transition metal (TM) - heavy rare earth (RE) ferrimagnetic alloys. In such alloys the moment held by the transition metal and the rare earth are antiferromagnetically coupled. The magnetic properties of such alloys (anisotropy, magnetization, exchange stiffness...) can easily be adjusted by varying the composition and the nature of the RE. For instance the net magnetization can be adjusted and a composition (X_{comp}) named the compensation composition for which the net magnetization is zero can be reached. Moreover TM-RE alloys prepared under certain growth conditions exhibit strong perpendicular anisotropy, e.g. $Tb_{1-X}Co_X$, TbCoFe, etc [3], We have then concentrated on Co_x Tb_{1-x}- ferrimagnetic alloys and both single layers and spin-valves have been grown by sputtering. The macroscopic magnetic properties were analyzed by Vibrating Sample Magnetometry (VSM) and SQUID measurements and by electrical transport measurements to study hall effect and Giant Magnetoresitance. Also high resolution and element specific XMCD magnetic soft X-ray microscopy was performed at the ALS in Berkeley. This technique is well suited for our material since the photon energy can be tuned to the Co edge a large contrast may be obtained even if the alloy net magnetization is zero.

Several $Tb_{1-X}Co_X$thin films for compositions close to compensation and different thicknesses have been grown. All samples have shown strong perpendicular anisotropy identified by a square hysteresis loop along the direction perpendicular to the surface and a non hysteretic loop along the in-plane direction. Figure 1 shows the magnetization of the alloy measured at room temperature for different concentration ranging from 74% Co to 88 % Co.

The compensation concentration at room temperature is found to be around 79% Co.

Si// Co_{88} Tb_{12} (20nm)/Cu (3.5nm)/ Co_{74} Tb_{26} (20nm) spin-valves have been grown. $Co_{74}Tb_{26}$ acts as the hard layer with a coercivity of 0,55 T, whereas $Co_{88}Tb_{12}$ acts as the soft layer . Also as $Co_{74}Tb_{26}$ magnetization is Tb dominant (X<79%), $Co_{88}Tb_{12}$ is Co dominant (X>79%). This explains the opposite signs of the hall coefficients for the soft and the hard layer.

By growing the $Co_{88}Tb_{12}$(20nm)/Cu (3.5nm)/ $Co_{74}Tb_{26}$ (20nm) spin-valve on a SiN membrane it was possible to image magnetic domains using X-ray magnetic microscopy using photon energy close to the Co edge (see figure 2). It was observed, that the coercivities of the minor-loops of the spin-valve were affected by the magnetic state of the hard layers. The coercivity of the soft layer decreases with increasing saturation of the hard layer.

This technique allows observing the domain structure of the hard and the soft layer at the same time. Thus the domain creation around the reversal of the soft layer could be imaged. We observed that a non saturated hard layer increases the probability to nucleate domains and to pin domain walls. This can be explained by dipolar field interactions [4]. This proves that in such systems it is possible to control the magnetization reversal i.e. the domain wall propagation in the soft layer by adjusting the magnetic domain structure inside the hard layer.

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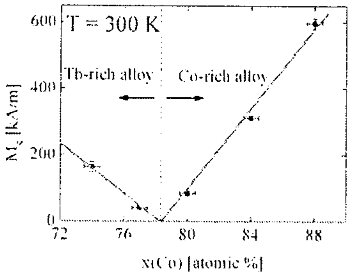
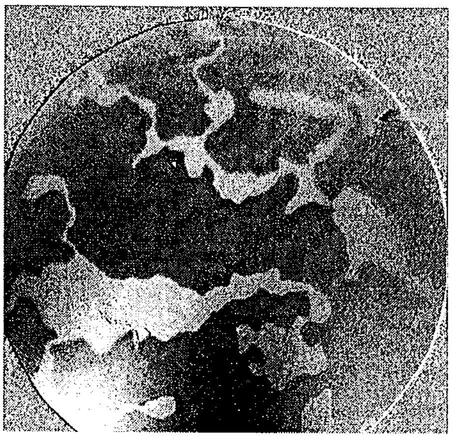


Saturation magnetization (MS) as a function of the Co-concentration of 80 nm of Tb1-X CoX alloys measured at room temperature.



XMCD-image (5x5 µm) of a CoTb spin-valve with non saturated hard-layer during the soft-layer reversal.