I-1

Magnetization Dynamics in Exchange-Biased Magnetic Elements

Choi, B.C., Hong, Y.K.[1*], Girgis, E., Abo. G.[1], Rudge, J., Kolthammer, J. and Bae, S[1]
Department of Physics & Astronomy, University of Victoria, Victoria, BC, Canada.
[1]Department of Electrical and Computer Engineering, University of Alabama, Tuscaloosa, AL, USA.

1. Introduction

The magnetization dynamics of vortex structures in patterned elements has received considerable attention during the last few years due to its possible applications inhigh-density magnetic storage devices. Recently, it was found that the vortex magnetization state can be controllably modified through exchange bias in the ferromagnetic disks by depositing antiferromagnetic layer and cool the samples in a magnetic field. Sort *et al* [1] presented in a static study the magnetic vorticescontrolled through the exchange bias at different cooling fields, however this studyraises the question how these cooling fields would influence the magnetization dynamics of exchange biased vortices. We present the study of magnetization dynamics in vortex structures controlled through the exchange bias in 10 micron square element of 12 nm $Ni_{80}Fe_{20}$/5 nm $Ir_{80}Mn_{20}$.

2. Method of Experiments

Arrays of 10 micron square elements with layer sequences of Ta(5 nm)/NiFe (15 nm)/IrMn(5 nm)/Ta(1 nm) were sputtered onto 15 µm-thick glass substrates and patterned into arrays of 10 µm wide squares using optical lithography and lift-off techniques. For all samples, the 5 nm Ta was deposited as a buffer layer and 1nm of Ta as a cap layer. The thin films were deposited in an ultra high vacuum *dc* magnetron sputtering system at an Ar pressure of 10^{-3} mbar, and the system base pressure was below 10^{8} mbar. The samples were heated to 600 K (i.e. above the blocking temperature, T_B, of the system) and subsequently cooled to room temperature. Dynamics in the magnetization process is measured using picosecond time-resolved scanning magneto optic Kerr microscope (TR-SKEM) [2].

3. Results and discussion

The dynamic properties of exchange-biased vortex magnetization were studied using time-resolved scanning Kerr microscope with a spatial resolution of 800 nm. The magnetic elements were placed on top of a 20 µm wide and 300 nm thick gold transmission line that carried a fast current pulse which generated a magnetic field pulse of 50 Oe with 240 ps rise time and 4 ns duration. The field pulse was applied in the opposite direction to the exchange-bias field. The magnetic field pulses were synchronously triggered by a mode-lockedTi:sapphire femtosecond laser at 0.8 MHz repetition rate. Fig. 1 shows the temporal evolution of nonequilibrium domain configuration of the magnetization component M_x for the NiFe/IrMn elements which were field cooled at H_{cool}=0 Oe (top panel) and 50 Oe (bottom panel), respectively. The numbers below the images indicate the time after a magnetic field pulse is applied at *t*=0 ns. The contrast in the images reflects the local degree of magnetization reversal, with dark areas corresponding to the longitudinal components of the magnetization along +xdirection (M_x), whereas bright area is M_x regions. For the zero field cooled sample, the magnetic image reveals a simple closure domain structure, where the vortex core is located at the center of the disk and four in-plane magnetization quadrants are separated by 90 Néel walls. At the time *t*=0.09 ns after the application of magnetic field pulse the domain configurations reveals a Landau flux-closure domain structure, which is typically found as the equilibrium state of micron-sized $Ni_{80}Fe_{20}$square elements. The bottom panel shows the dynamic images of the 50 Oe field cooling sample.

At the beginning of the pulse, the images show a magnetization configuration where the magnetization mostly aligned along the exchange bias field direction except for the top part of the element. It is clear that the vortex is not centered which leads to net remnant value. This clearly demonstrates the effect of the field cooling on the remanent magnetization state. With increasing time after magnetic pulse, the magnetization rotate in the magnetic pulse field direction and the vortex core simply moves through the sample. Fig. 2 shows the trajectory of vortex core motion for H_{cool}=0Oe (left panel) and 50 Oe (right panel). For zero cooling field, the initial displacement is found to be perpendicular to the applied field pulse direction, whichis in agreement with the report by Raabe et al [3]. After initial displacement of the core it carries out gyrotropic motion. A drastically different behavior of vortex core dynamics is found for the element fabricated in the presence of a stronger H_{cool}=50 Oe, in which no gyrotropic motion is observed. This observation suggests a critical influence of the cooling field on the vortex core dynamics.

4. Conclusions

In conclusion the vortex dynamics in exchange-biased $Ni_{80}Fe_{20}/Ir_{80}Mn_{20}$ has been studied using time-resolved scanning magneto optic Kerr microscope. A drastic change in the core motion in response to magnetic field pulse is observed. Even though it is not directly accessible to identify the core polarity due to the limited spatial resolution, the polarity of the vortex core is concluded not to flip since the core circulation direction does not reverse throughout the dynamic process.

5. References

[1] B J. Sort, et al. Phys. Rev. Lett. 97, 067201 (2006).
[2] B.C. Choi et al., Phys. Rev. Lett. 95, 237211 (2005).
[3] J. Raabe et al., Phys. Rev. Lett. 94, 217204 (2005).

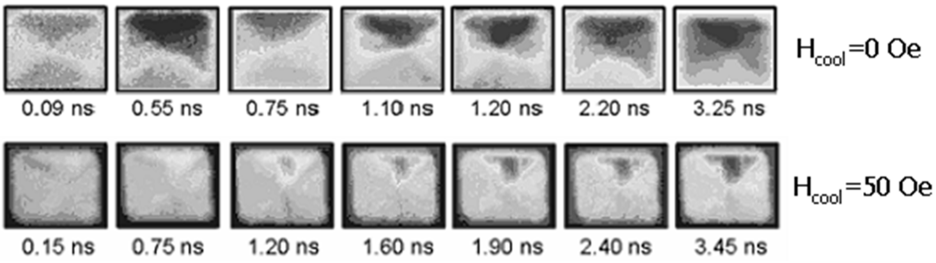

Fig. 1. Time evolution of longitudinal magnetization component (M_x) after a magnetic field pulse is applied at t=0 ns.

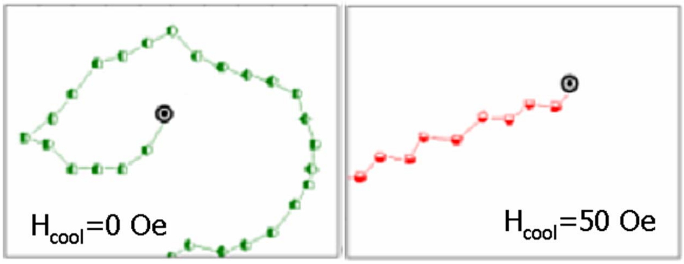

Fig. 2. Trajectory of vortex core motion in response to a magnetic field pulse.