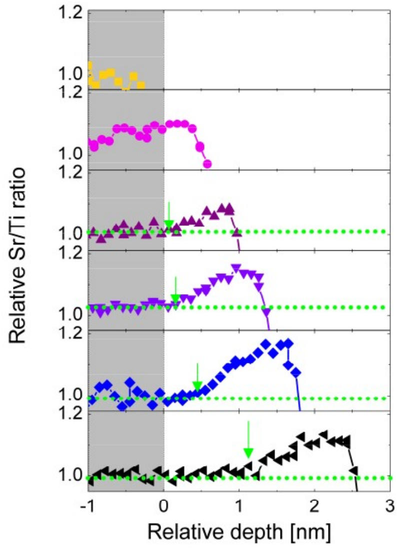

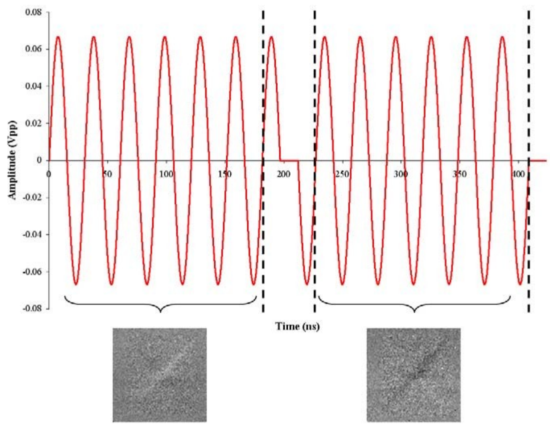

SLS Symposium on

Interfacial Conductivity and Magnetic Vortices

Tuesday, October 1, 2013

10:00 to 11:45, WBGB/019

10:00 Chemistry and structure of homoepitaxial STO films and their influence on oxide heterostructures
<u>M.L. Reinle-Schmitt</u>, C. Cancellieri, A. Cavallaro, S.J. Leake, C.W. Schneider, E. Pomjakushina, M. Medarde, J.A. Kilner and P.R. Willmott

10:30 Vortex Core Reversal in Heterogeneous Magnetic Nanostructures
<u>P. Wohlhüter</u>, S. E. Stevenson, M. T. Bryan, C. Moutafis, J. Raabe, G. Hrkac, L. J. Heyderman

11:00 Coffee

11:15 Magnetic Vortex Core Switching observed with Scanning Transmission X-ray Microscopy
<u>S. E. Stevenson</u>, P. Wohlhüter, C. Moutafis, P. Warnicke, S. Gliga, C. Quitmann, L. J. Heyderman, J. Raabe

Chemistry and structure of homoepitaxial STO films and their influence on oxide heterostructures

M.L. Reinle-Schmitt[1], C. Cancellieri[1], A. Cavallaro[2], S.J. Leake[1], C.W. Schneider[1], E. Pomjakushina[1], M. Medarde[1], J.A. Kilner[2] and P.R. Willmott[1]

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Complex oxides interfaces, and in particular the interface between $LaAlO_3$ (LAO) and $SrTiO_3$ (STO), have been the subject of intensive research in the last years [1, 2]. The unexpected interfacial conductivity between these band insulators may be particularly interesting for future integrated oxide-based electronic devices. Attempts to grow related structures, such as LAO on homoepitaxial-STO (h-STO) layers, or multilayers have been made. However as far as we know, the new devices do not generally exhibit similar interfacial properties as standard LAO grown on STO substrate [3]. In order to understand the loss of interfacial conductivity when more than a critical thickness of nominally homoepitaxial STO (see Fig.1) is inserted between a LAO film and a STO substrate, the properties of single crystal STO substrates and h-STO films grown by pulsed laser deposition have been compared. In particular the chemical composition and the structure of h-STO investigated by low-energy ion scattering and surface x-ray diffraction, show that, for insulating interfaces, a Sr-rich region (see Fig.2) is present between the LAO and h-STO. Furthermore, an increase in the lattice parameter of LAO is observed, indicating a similar origin of the conductivity with and without insertion of the h-STO thin film.

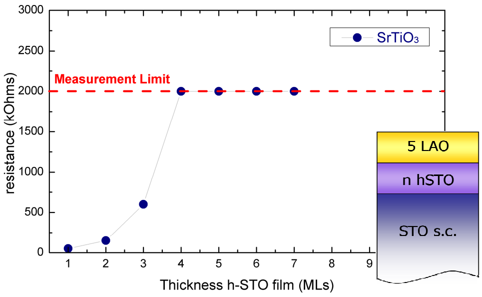

Figure 1: Dependence of the room-temperature resistance of 5 ML LAO/h-STO/STO single crystal on the thickness of the h-STO layer

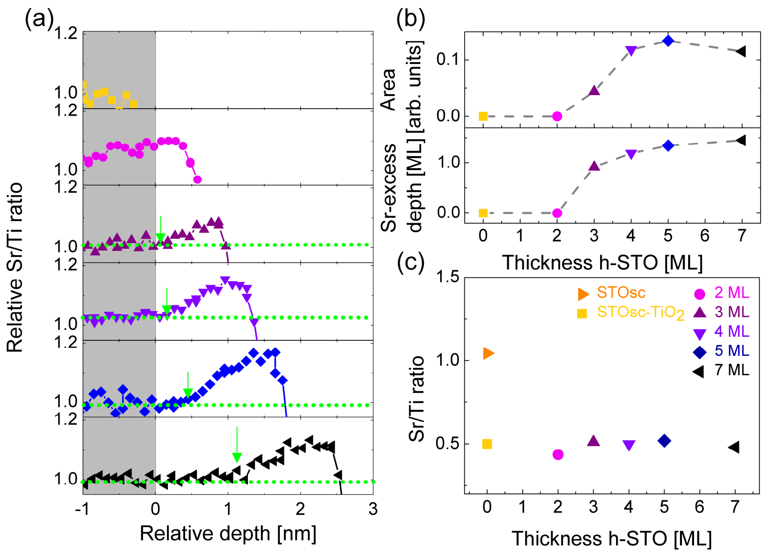

Figure 2: (a) Depth profile across the interface of the Sr/Ti ratio for different thicknesses of h-STO films and a bare TiO_2-terminated STO single crystal for comparison. (b) h-STO thickness dependency of the area below the Sr/Ti ratio curve and extent of the Sr-rich region. (c) h-STO thickness dependency of the surface Sr/Ti ratio of the same samples

[1]. A. Ohtomo and H. Y. Hwang, Nature **427**, 423 (2004).
[2]. S. Thiel, G. Hammerl, A. Schmehl, C. W. Schneider, and J. Mannhart, Science **313** (2006).
[3]. T. Fix, J. L. MacManus-Driscoll, and M. G. Blamire, Appl. Phys. Lett. **94,** 172101 (2009).

Vortex Core Reversal in Heterogeneous Magnetic Nanostructures

P. Wohlhüter [1], S. E. Stevenson [2], M. T. Bryan [3], C. Moutafis [2],
J. Raabe [2], G. Hrkac [3,4], L. J. Heyderman [1]

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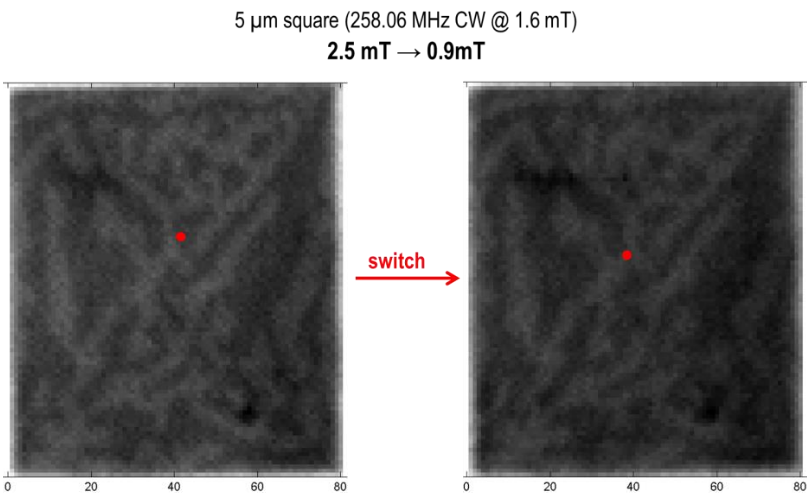
Magnetic squares of micron size are usually in a Landau state. One characteristic of such a Landau state is the in-plane orientation of all spins except for those in the very centre, where they point out of the plane. This area is called the vortex core. A vortex core can point either up or down. Thus the polarity of a vortex core has great potential for binary data storage applications.

There are two known processes that can reverse the vortex core polarity: The nucleation and annihilation of a vortex-antivortex core pair [1] or the nucleation of a Bloch point [2]. However, recent simulations by Bryan *et al*. [3] show that a third reversal process – the Bloch core reversal – exists in bilayer square elements. Due to magnetic anisotropy variations, which are induced by the layer stack, an in-plane vortex core and out-of-plane maze domains can co-exist. A Bloch core reversal occurs when the vortex core of the in-plane magnetised layer crosses a maze domain wall of the out-of-plane magnetised layer. Simulations also show that the coupling between the layers forces a temporary suppression of the vortex core magnetisation. A further displacement of the vortex core reverses its polarity, since relaxation of the core spins occurs in a domain with opposite magnetisation.

We show the first evidence of the experimental observation of a Bloch core reversal in a [Co/Pd]/Py bilayer system by means of Scanning Transmission X-ray Microscopy (STXM) imaging.

[1] B. van Waeyenberge *et al.*, Nature **444**, 461-464 (2006).
[2] A. Thiaville *et al.*, Phys. Rev. B **67**, 094410 (2003).
[3] M. T. Bryan *et al.*, “Dynamic loss of vortex core magnetization during reversal in heterogeneous nanostructures” (unpublished, 2013).



Example of a Bloch core reversal in a 5µm [Co/Pd]/Py square. The application of a continuous wave excitation allowed for determining the vortex core polarity while a constant external field displaced the vortex core. A decrease of the external field from 2.5mT to 0.9mT moved the vortex core from a black into a white domain, thereby reversing the vortex core polarity.

Magnetic Vortex Core Switching observed with Scanning Transmission X-ray Microscopy

S. E. Stevenson [1], P. Wohlhüter [2], C. Moutafis [1], P. Warnicke [1], S. Gliga [2],
C. Quitmann [1], L. J. Heyderman [2], J. Raabe [1]

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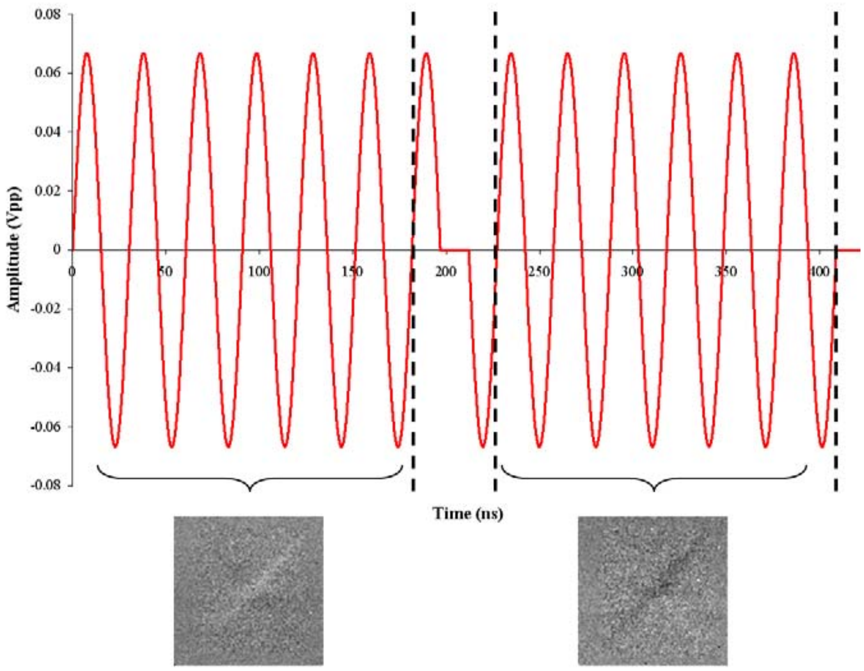
The out-of-plane magnetic vortex core in discs and squares can be likened to a magnetic needle, surrounded by curling in-plane magnetisation. Its high stability and bi-polarity allow for potential applications in binary data storage. Precessional switching of the vortex core has previously been reported, typically by employing bursts or alternating excitations of high enough amplitude while exploiting the gyrotropic mode of the vortex core [1-3]. We present a method of dynamically switching the vortex core polarity without the need for high amplitude excitations or bursts.

A low-amplitude continuous-wave (CW) excitation applied close to resonance (33.02 MHz) causes the vortex core to gyrate in a 40 nm thick $Ni_{80}Fe_{20}$ square of 6 µm side length. The CW excitation is then paused for half a cycle, before resuming with a 180° phase shift. During the half-cycle pause where no excitation is applied, the vortex core polarity is switched. We will discuss the physical phenomena behind this reproducible switching process with a view to contribute to the general understanding of micromagnetic switching processes. Developing a full understanding of such processes will ultimately lead to an optimisation of switching schemes for further practical applications. The results we present are a preliminary analysis of data measured using Scanning Transmission X-ray Microscopy at the PolLux beamline of the SLS.

[1] Van Waeyenberge, B., *et al.*, Nature **444**, 461 (2006)
[2] Yamada, K., *et al.*, Nat. Mat. **6**, 270 (2007)
[3] Curcic, M., *et al.*, Phys. Rev. Lett. **101**, 197204 (2008)



Low-amplitude CW excitation at 33.02 MHz with phase shifts for switching the vortex core. Contrast in experimental images shows opposite gyration direction of vortex core between phase shifts, which indicates vortex core polarity is switched.