H2020 FET-Open Research and Innovation Actions Project Number 766566
Antiferromagnetic spintronics (ASPIN)

Work package 1, Deliverable D1.2: Report on XMLD-PEEM measurements of electrical-pulse induced domain reconfigurations

This report summarizes the work of the ASPIN project consortium on X-ray magnetic linear dichroism measurements of Néel vector reorientations and domain reconfigurations in CuMnAs. We give references to the corresponding publications featuring details of these results and list the contributing teams from the consortium comprising: Institute of Physics in Prague (IOP), University of Nottingham (NOT), Max-Planck Institutes (MPG), IGS Ltd. (IGS), Charles University in Prague (CHU), Johannes Gutenberg University in Mainz (JGU).

Contents

1 Imaging Current-Induced Switching of Antiferromagnetic Domains in CuMnAs

Contributing teams: NOT, IOP

The magnetic order in antiferromagnetic materials is hard to control with external magnetic fields. Using x-ray magnetic linear dichroism microscopy, we show in this work [1] that staggered effective fields generated by electrical current can induce modification of the antiferromagnetic domain structure in microdevices fabricated from a tetragonal CuMnAs thin film. A clear correlation between the average domain orientation and the anisotropy of the electrical resistance is demonstrated, with both showing reproducible switching in response to orthogonally applied current pulses. However, the behavior is inhomogeneous at the submicron level, highlighting the complex nature of the switching process in multidomain antiferromagnetic films (see Fig. 1).

2 Current polarity-dependent manipulation of antiferromagnetic domains

Contributing teams: NOT, IOP

Antiferromagnets have several favourable properties as active elements in spintronic devices, including ultra-fast dynamics, zero stray fields and insensitivity to external magnetic fields. Tetragonal CuMnAs is a testbed system in which the antiferromagnetic order parameter can be switched reversibly at ambient conditions using electrical currents. In previous experiments, orthogonal in-plane current pulses were used to induce 90deg rotations of antiferromagnetic domains and demonstrate the operation of all-electrical memory bits in a multi-terminal geometry. In this work [2] we demonstrate that antiferromagnetic domain walls can be manipulated to realize stable and reproducible domain changes using only two electrical contacts. This is achieved by using the polarity of the current to switch the sign of the current-induced effective field acting on the antiferromagnetic sublattices. The

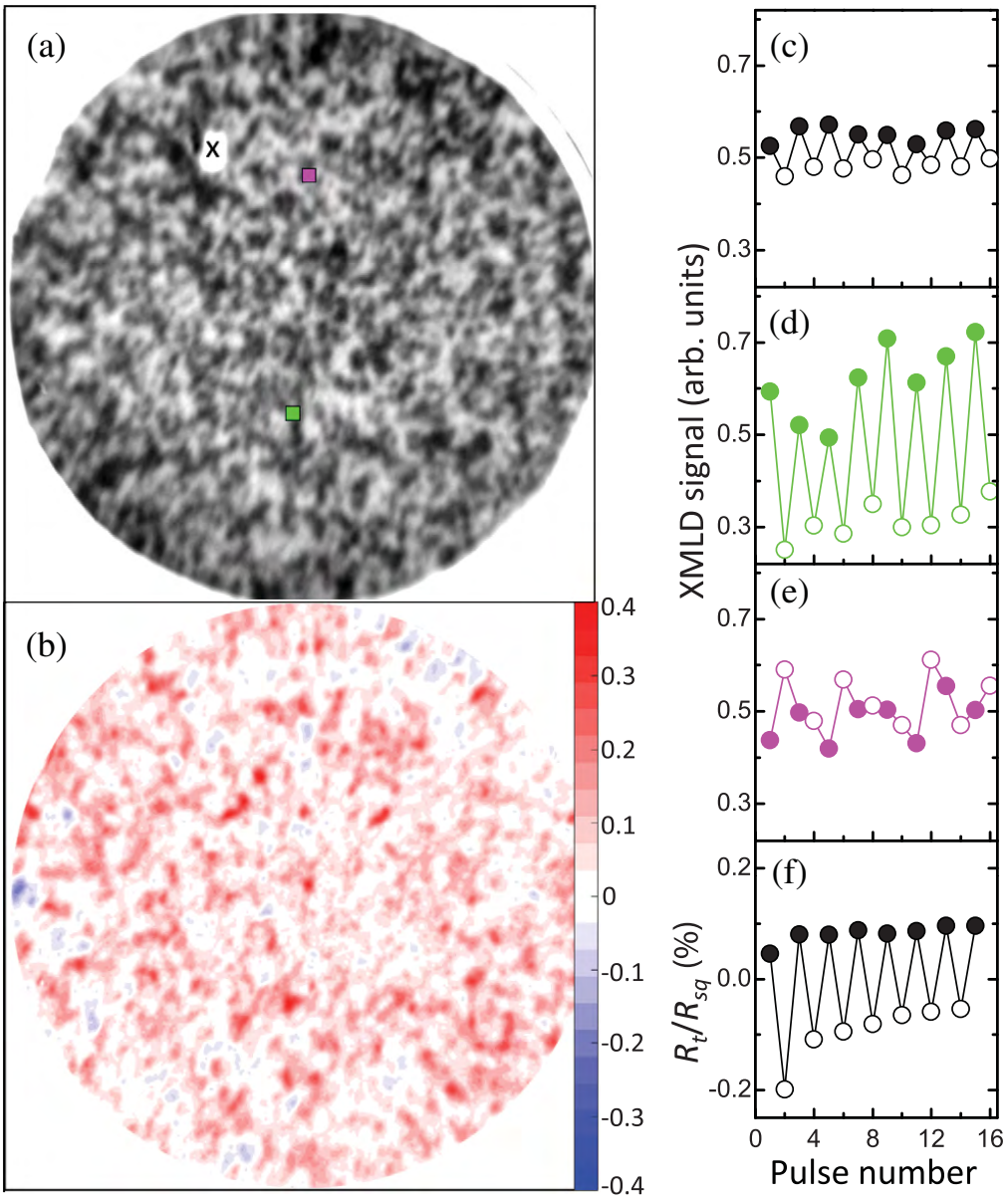

Figure 1: Comparison of XMLD-PEEM and resistance measurements of the electrically induced multi-domain reconfiguration in CaMnAs [1].

resulting reversible domain and domain wall reconfigurations are imaged using X-ray magnetic linear dichroism combined with photoemission electron microscopy (XMLD-PEEM), and can also be detected electrically. Switching by domain-wall motion can occur at much lower current densities than those needed for coherent domain switching (see Figs. 2-4).

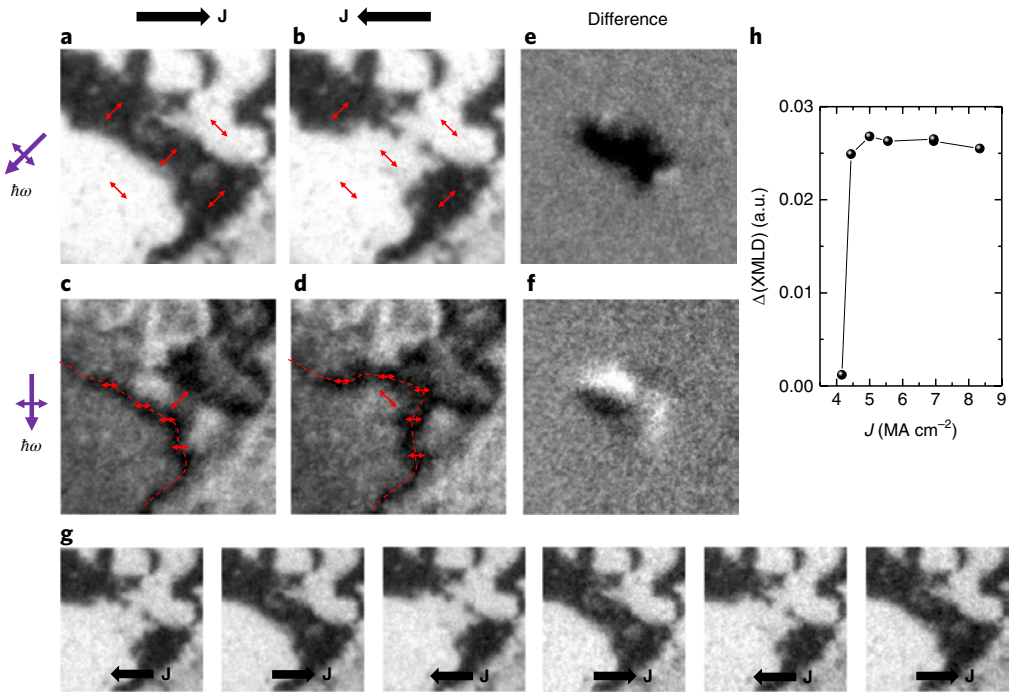

Figure 2: XMLD-PEEM images of antiferromagnetic domain switching by current-induced domain-wall motion [2].

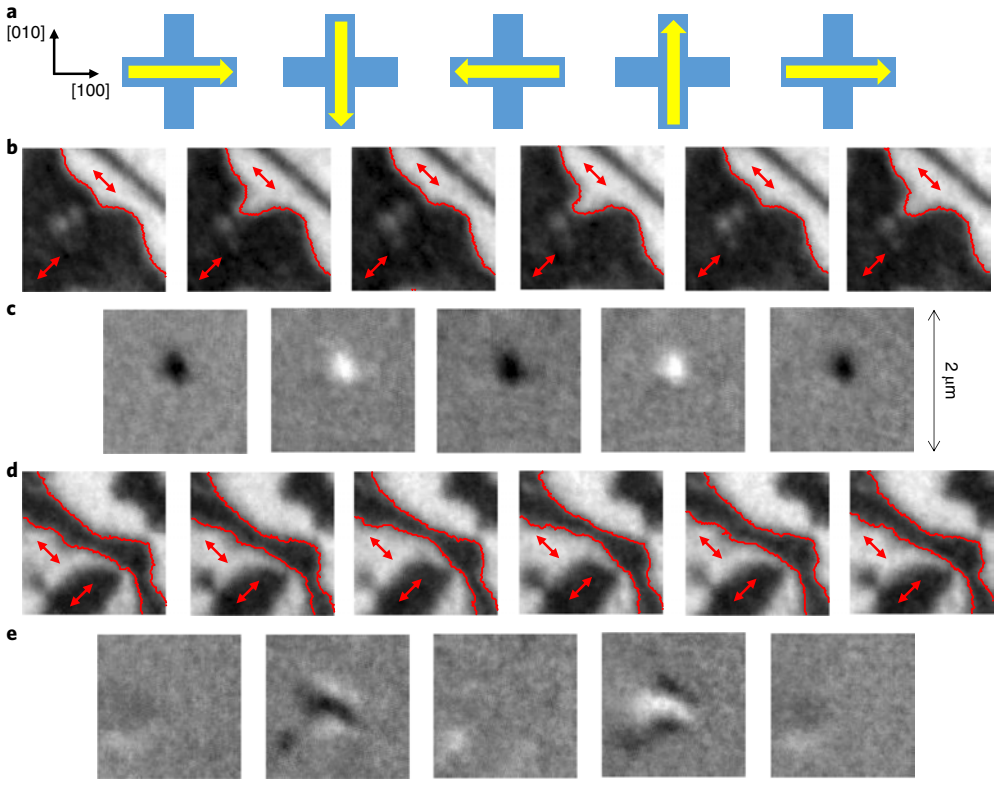

Figure 3: XMLD-PEEM images of the dependence on the direction of the current pulses [2].

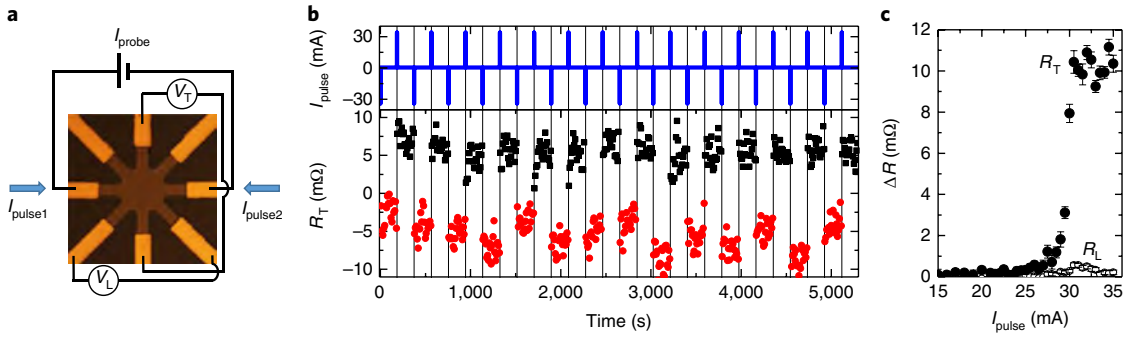

Figure 4: Electrical detection of current-induced switching in the same CuMnAs structure as in Figs. 1 and 2 [2].

3 Control of antiferromagnetic spin axis orientation in bilayer Fe/CuMnAs films

Contributing teams: NOT, IOP, MPG

Using x-ray magnetic circular and linear dichroism techniques, we have demonstrated in this work [3] a collinear exchange coupling between an epitaxial antiferromagnet, tetragonal CuMnAs, and an Fe surface layer. A small uncompensated Mn magnetic moment is observed which is antiparallel to the Fe magnetization. The staggered magnetization of the 5 nm thick CuMnAs layer is rotatable under small magnetic fields, due to the interlayer exchange coupling (see Fig. 5). This allows us to obtain the x-ray magnetic linear dichroism spectra for different crystalline orientations of CuMnAs in the (001) plane. This is a key parameter for enabling the understanding of domain structures in CuMnAs imaged using x-ray magnetic linear dichroism microscopy techniques.

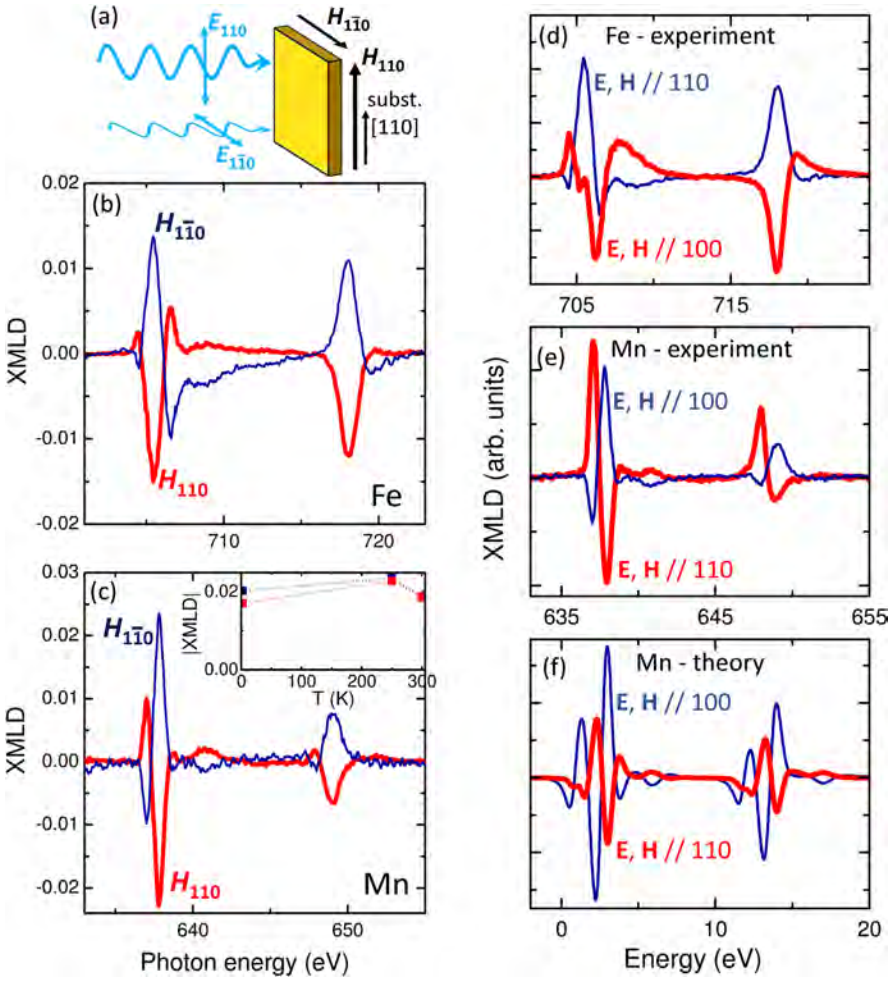

Figure 5: Rotation of the antiferromagnetic moments in CuMnAs due to exchange coupling to Fe as revealed from the anisotropic XMLD spectra [3].

References

[1] Grzybowski, M. J. *et al.* Imaging Current-Induced Switching of Antiferromagnetic Domains in CuMnAs. *Physical Review Letters* **118**, 057701 (2017). 1607.08478.

[2] Wadley, P. *et al.* Current polarity-dependent manipulation of antiferromagnetic domains. *Nature Nanotechnology* **13**, 362–365 (2018). URL http://www.nature.com/articles/s41565-018-0079-1. arXiv:1711.05146.

[3] Wadley, P. *et al.* Control of antiferromagnetic spin axis orientation in bilayer Fe/CuMnAs films. *Scientific Reports* **7**, 11147 (2017).