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## Principle publication and authors

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# INVESTIGATION OF INDUCED Pt MAGNETIC POLARISATION IN Pt/Y<sub>3</sub>Fe<sub>5</sub>O<sub>12</sub> BILAYERS

Recently, a novel magnetoresistive effect was discovered in Pt deposited on ferrimagnetic Y<sub>3</sub>Fe<sub>5</sub>O<sub>12</sub> (YIG) thin films, which is fundamentally different from the other magnetoresistive phenomena [1,2]. The main characteristic of this novel effect found in normal-metal/ferrimagnetic insulator (NM/FMI) bilayers is the dependence of the NM resistance on the magnetisation direction in the FMI. A possible explanation of the effect is based on static magnetic proximity effects, resulting in a finite magnetic polarisation in the NM layer as known for normal-metal/ferromagnetic metal (NM/FMM) heterostructures. In turn, this leads to ferromagnetic like transport properties in the NM thin film [2]. An alternative explanation is based on the (inverse) spin Hall effect (SHE) in the NM layer. A charge current flowing in the NM thin film is accompanied by a perpendicular spin current due to the SHE. This spin current is absorbed or reflected at the interface to the FMI depending on its magnetisation orientation. While the reflected spin current induces a charge current via the inverse SHE leaving the longitudinal resistance of the NM layer unchanged, the spin current transmitted across the NM/FMI interface represents an

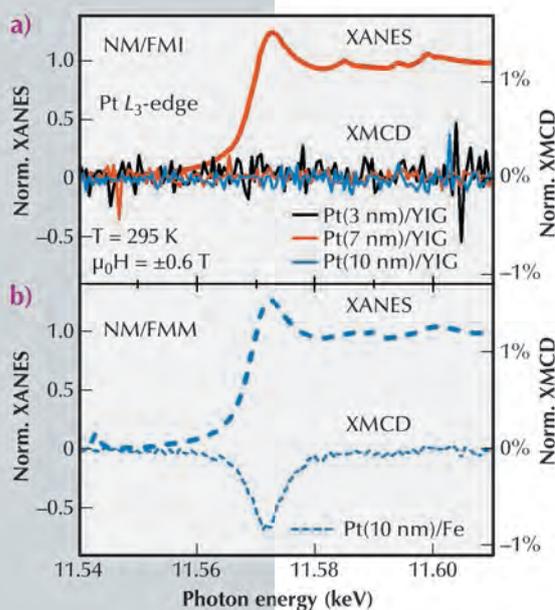
additional dissipation channel and thus increases the resistance [1,3].

The fundamental difference of both models is the presence or absence of an induced magnetic polarisation in the NM layer in equilibrium. Therefore, a careful investigation of this induced magnetic polarisation in NM/FMI heterostructures is essential for the correct interpretation of the reported magnetoresistance in Pt/YIG bilayers.

We investigated a series of Pt/YIG samples by XMCD at the Pt L<sub>3</sub>-edge. Taking advantage of an ultra-high vacuum cluster system, the ultrathin Pt layers with different thicknesses (3 nm, 7 nm, 10 nm) were deposited *in situ* by electron-beam evaporation immediately after the pulsed-laser deposition of the about 62 nm thick YIG films on (111)-oriented Y<sub>3</sub>Al<sub>5</sub>O<sub>12</sub> substrates. For comparison, we fabricated a NM/FMM sample composed of a 10 nm thick Pt layer on a 10 nm thick Fe film.

X-ray absorption near edge spectra (XANES) were recorded at the beamline ID12 around the Pt L<sub>3</sub>-edge with right and left circularly polarised light under grazing incidence as well as positive and negative magnetic fields using the total fluorescence yield (TFY) detection mode. The X-ray magnetic circular dichroism (XMCD) was calculated after averaging up to 34 single XANES per bilayer either with right and left circularly polarised light or while applying positive and negative magnetic fields. **Figure 106a** shows the XANES normalised to an edge jump of unity of a Pt(7 nm)/YIG bilayer and the XMCD spectra of all measured Pt/YIG bilayers around the Pt L<sub>3</sub>-edge. The XMCD signals do not show any indication of a finite induced magnetic moment in Pt down to a noise level of < 0.2%. To cross-check our experimental approach, XANES and XMCD spectra were recorded from the Pt(10 nm)/Fe(10 nm) reference

**Fig. 106:** a) Normalised XANES and XMCD spectra of normal-metal/ferromagnetic insulator (NM/FMI) samples composed of Pt layers with different thicknesses (3 nm, 7 nm, 10 nm) fabricated on YIG thin films. b) Normalised XANES and XMCD spectra of the normal-metal/ferromagnetic metal (NM/FMM) reference sample, consisting of a Pt(10 nm)/Fe(10 nm) bilayer.



sample at the Pt  $L_3$ -edge (**Figure 106b**). Here, a clear XMCD signal is visible, demonstrating the presence of induced magnetic moments in NM/FMM heterostructures. By integrating the XMCD spectra, the total moment of Pt is calculated via the standard magneto-optical sum rules to  $(0.0325 \pm 0.0004) \mu_B$  per Pt atom in the Pt/Fe bilayer. Using the same method, an upper limit for the induced total magnetic moment of  $(0.003 \pm 0.001) \mu_B$  per Pt can be estimated in Pt/YIG bilayers. If we consider that only the first layer of the Pt thin film is polarised, then the Pt atoms at the interface would carry an induced moment, which is

at least 30 times smaller than that of the Pt atoms at the interface in Pt/Fe bilayers.

In summary, taking advantage of the element-specific XMCD technique, we found that the induced magnetic polarisation of Pt in Pt/YIG bilayers is negligible and at least 30 times smaller than in the corresponding Pt/Fe reference sample. With respect to the reported novel magnetoresistive effect in Pt/YIG bilayers, our data support the model explanation based on spin currents due to the spin Hall effect [1,3] and disagree with explanations based on magnetic proximity [2].

#### References

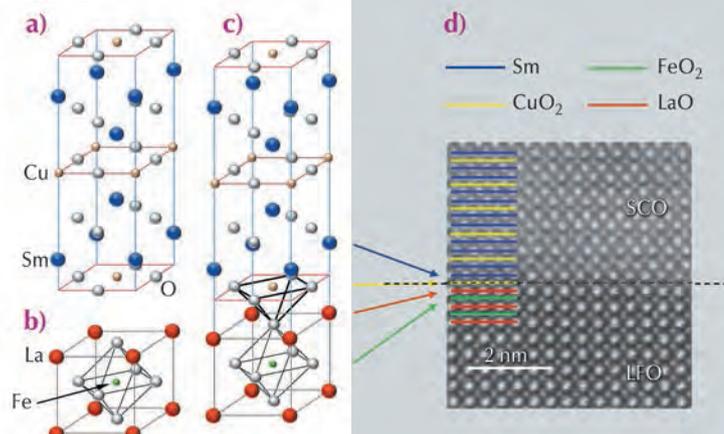
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## CHARGE TRANSFER AT EPITAXIAL INTERFACES

Differences in the work functions between the constituents of semiconductor interfaces are known to cause charge transfer, band bending and the formation of space charge regions. At interfaces of correlated oxides, the situation can be even more complex since the charge, orbital and spin degrees of freedom can be modified. The materials forming the interface may experience significant modification of their electronic response from the variations in carrier density associated with charge transfer. These modifications occur as a consequence of the very different electronic ground states that coexist in narrow regions of the phase diagrams [1]. We have studied the effect of charge transfer and modified bonding at the interface formed between two Mott-insulators:  $\text{LaFeO}_3$  (LFO) and  $\text{Sm}_2\text{CuO}_4$  (SCO). While  $\text{LaFeO}_3$  remains insulating and with an antiferromagnetic ground state when moderately doped,  $\text{Sm}_2\text{CuO}_4$  becomes metallic and even superconducting upon doping with

electrons. In experiments using X-ray absorption spectroscopy with linear polarisation at beamline ID08, we have shown that charge transfer occurs at this interface and as a consequence the heterostructure formed by two insulating materials becomes metallic.

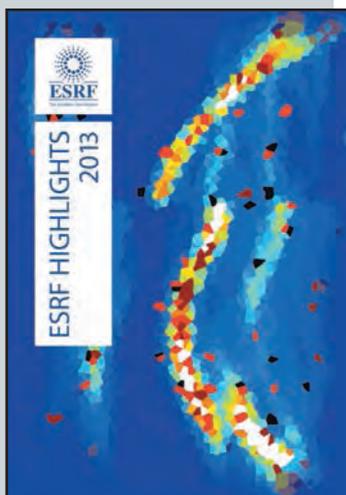
We have grown superlattices consisting of six bilayers of 14 unit cells (u.c.) of LFO and N u.c. SCO ( $[\text{LFO}_{14}/\text{SCO}_N]_6$ ) on  $\text{TiO}_2$  terminated  $\text{SrTiO}_3$  (STO) substrates in a high-pressure pure oxygen sputtering system. Thin films of LFO and SCO were also grown as control samples. The unit cell of SCO and LFO and the schematic of the resulting interface structure are shown in **Figure 107**. The heterostructures are fully strained



**Fig. 107:** Crystal structure of (a)  $\text{Sm}_2\text{CuO}_4$  (T'-phase), (b) pseudocubic representation of  $\text{LaFeO}_3$ , and (c) interface formed by these compounds. In (c) the interfacial Cu-O pyramid is highlighted. (d) High-resolution scanning electron microscopy image of a  $[\text{LFO}_{14}/\text{SCO}_4]_6$  heterostructure.

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