EUROPEAN SYNCHROTRON RADIATION FACILITY

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Experiment Report Form

ESRF	**Experiment title:** Investigating giant directional asymmetry in superconductivity and magnetoresistance of Iridate/Cuprate heterostructures using X-ray absorption spectroscopy (XMLD/XMCD).	**Experiment number**: 91932 HC-5020
Beamline: ID12	**Date of experiment**: from: 24.01.2023 to: 30.01.2023	**Date of report**: 27.02.2023 *Received at ESRF:*
Shifts: 15	**Local contact(s)**: Dr. Fabrice Wilhelm and Dr. Andrei Rogalev	

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In this experiment, we investigated the electronic structure of Ir atoms in thin film heterostructures of Sr_2IrO_4(SIO)/$YBa_2Cu_3O_7$(YBCO) heterostructures using X-Ray absorption spectroscopy (XAS) at the Ir L edge. We tested samples on three different substrates with respect to their background and found a good signal to noise ratio with $SrTiO_3$ (STO) and $LaAlO_3$ (LAO) substrates. STO was found to be most suitable for the experiment.

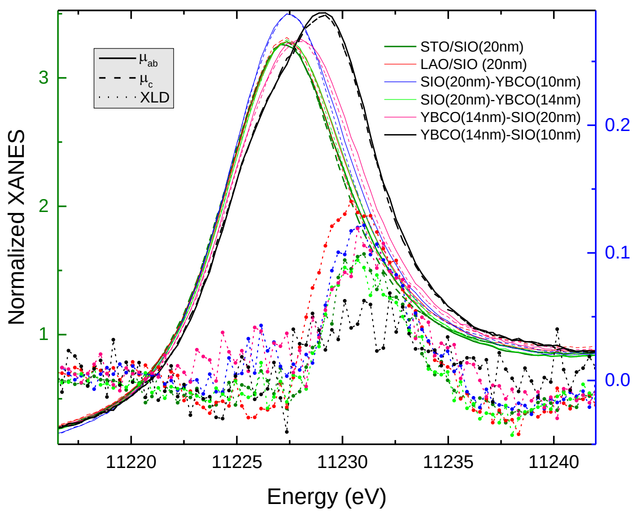

Figure 1: XANES and XLD of the S/Y and Y/S heterostructures

The linear dichroism (XLD) is very small, showing a large spin-orbit coupling (SOC) in the SIO layers. The peak position of the Ir L3 peak is found to be blue shifted for samples where the YBCO is grown underneath the SIO layer with respect to a bare SIO layer or when the YBCO layer is grown on top of SIO. No temperature dependence of the XLD and XAS signal are found.

The branching ratio is calculated as the relation of the peak area between the L3 and L2 peak. We find values between 4.56(24) and 5.62(29) for our samples. This deviates significantly from the value 2 that is expected in the single electron quantum mechanical picture. It shows the large SOC in the SIO layers. These values agree well with the ones for bare SIO thin films and bulk reported before [1,2].

Using X-Ray Magnetic Circular Dichroism (XMCD), we were able to see ferromagnetic moments on the Ir atoms. SIO has a peculiar magnetic structure with antiferromagnetic moments canted by about 12.2° [3]. Under a relatively small magnetic field of $\sim 0.2\,T$, a spin flop transition is expected to lead to a non-zero magnetization of the Ir atoms [4].

Indeed, we clearly see an XMCD signal at the Ir L3 edge for three of our four measured samples, as shown below: The bare SIO layer, the sample with the structure STO/SIO(20nm)/YBCO(14nm), and the one with STO/YBCO(14nm)/SIO(20nm) show a ferromagnetic signal, while the sample with composition STO/YBCO(14nm)/SIO(10nm) does not show any magnetic signal. These findings are confirmed by both energy scans and hysteresis loops of the magnetic field at the peak position (see below).

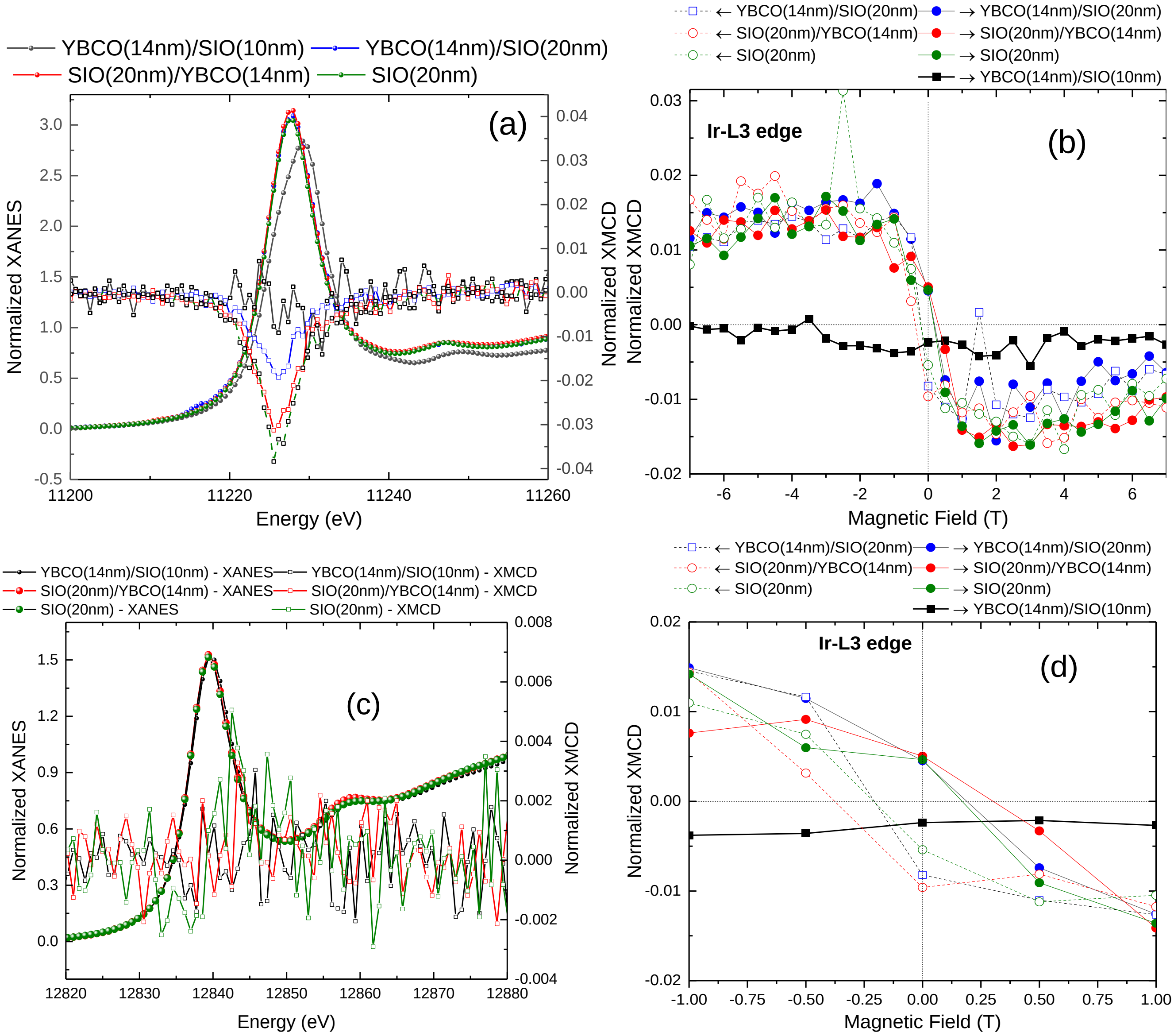

Figure 2. (a)XANES and XMCD showing diminished magnetization for Y/S (14nm/10nm) bilayer at Ir-L3 edge, (b) and (d) XMCD hysteresis loop, (c) *)XANES* at Ir-L2 edge: *no clear XMCD.*

Despite large statistics, none of the samples showed an XMCD signal at the Ir L2 edge. It has been reported before on SIO powder samples that the XMCD signal at the L2 edge is much weaker [2] than at the L3 edge. Our results are very well compatible with this. The cause is likely to be a cancellation between spin and orbital moments at the L2 edge.

The main finding of the experiment is the vanishing magnetism combined with the blue shift of the absorption peak for the 10nm thick SIO sample with YBCO grown below it. It opens up further questions and calls for a more detailed thickness dependence of the SIO layers. It is also an open question, whether the vanishing magnetism is purely a thickness phenomenon or if it is influenced by the proximity to YBCO. A detailed study of the XMCD signal of SIO layers with various thicknesses with and without YBCO grown below them will be subject of a further project.

References:

[1] Liu *et al.*, Phys.Rev.Mat. **1**, 075004 (2017) ;[2] Haskel *et al.*, Phys.Rev.Lett. **109**, 027204 (2012)) ; [3] Boseggia *et al.*, J. Phys.: Condens. Matter, **25**, 422202 (2013) [4] Lu *et al.*, Adv. Mater. **2020**, 1904508 (2019) [5]