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Report:
During our beamtime on ID32, we attempted to investigate magnetic coupling between the intrinsic topological insulator (MTI) family $MnBi_2Te_4$, i.e., $(MnTe)_m(Bi_2Te_3)_n$, and ferromagnetic overlayers using x-ray magnetic linear and circular dichroism (XMLD/XMCD). We were able to obtain fully characterized MBT-147 ($m = 1$, $n = 2$) bulk crystals, which we cleaved in ultra-high vacuum in our preparation chamber in Oxford, before coating them a ferromagnetic layer. We produced different Co/Pt layers with in- and out-of-plane magnetic anisotropy, as well as a Si-capped permalloy control sample. Our goal was to study the coupling between the two ferromagnetic systems in an attempt to raise the transition temperature of the MTI. As the Mn-based MTI samples are known to be problematic in terms of the homogeneity of the Mn doping, and as a final verdict over the quality of the cleaved pieces requires synchrotron radiation, we also brought Mn_2TiO_4 (MTO) backup samples which had not been investigated with XMCD before.

Experimental

The MBT samples show a characteristic switching sequence in SQUID magnetometry, with a Néel temperature of $\sim$13 K and a Curie temperature of $\sim$25 K. We carried out XMCD measurements at the Mn and Co L edges above and below these temperatures, and measured the respective hysteresis loops in fluorescence yield and total electron yield mode.
Additionally, we measured three MTO backup samples, each with different crystal structure/orientation, i.e., cubic (001) and (111), and a tetragonal sample.

In SQUID magnetometry, the cubic MTO sample shows a compensation between the two magnetic ions, i.e., Mn^{2+} and Ti^{2+}, at $\sim$65 K at low field. This was the primary effect we attempted to probe using temperature and field dependent XMCD measurements at the Mn and Ti L edges between 30 and 90 K.

Conclusion

As it turned out, the magnetic anisotropy of all ferromagnetic heterostructures on MBT was in-plane, and not out-of-plane as intended. While the thin film heterostructures on sapphire (grown in parallel to the MBT samples on the same sample holder) showed the desired properties, the growth recipes were not transferable to MBT. Given that our samples were small (and air-sensitive), their pre-characterization prior to the beamtime is not straightforward. As a result, the possibly observed coupling between MBT and [Co/Pt] is weak and requires a more careful in-depth analysis, before a final conclusion can be drawn.

Measuring the Ti edge in MTO proved to be difficult due to the low photon energy required. This resulted in a poor signal-to-noise ratio of the TEY signal. Attempts to improve it by applying a magnetic field failed due to the strong field dependence of the magnetic state, i.e., the low saturation field. While we believe that we have seen a change in the behavior of Ti at $\sim$45-50 K, the small signal makes it difficult to precisely determine the transition temperature, or characterize the nature of this transition, without a more comprehensive background subtraction and data analysis. This will be performed in the coming weeks. Additionally, more analysis will be required to ascertain the contributions to the XAS from the two Ti^{3+} and Ti^{4+} ions present in cubic MTO.