Ferromagnetism and Topological Insulators - A Love-Hate Relationship

L. J. Collins-McIntyre[1], P. Schönherr[1], S.-L. Zhang[1], A. A. Baker[1], Y.L. Chen[1], T. Hesjedal[1], A. I. Figueroa[2], L. Shelford[2], G. van der Laan[2], N.-J. Steinke[3], C. J. Kinane[3], T. R. Charlton[3], D. Alba-Veneroa[3], S. Langridge[3], S. E. Harrison[4], J. S. Harris[4], A. Pushp[5], A. J. Kellock[5], S. S. P. Parkin[5]

[1]*Department of Physics, Clarendon Laboratory, University of Oxford, Oxford, OX1 3PU, UK*
[2]*Magnetic Spectroscopy Group, Diamond Light Source, Didcot, OX11 0DE, UK*
[3]*ISIS, STFC, Rutherford Appleton Lab, Didcot, OX11 0QX, United Kingdom*
[4]*Department of Electrical Engineering, Stanford University, Stanford, California 94305, USA*
[5]*IBM Almaden Research Center, 650 Harry Road, San Jose, California 95120, USA*

Topological insulators (TIs) have caught the attention and captured the imagination of condensed matter physicists, materials scientists, and electrical engineers alike, as they promise dissipationless carrier transport at room-temperature. TIs host a gapless surface state protected by time reversal symmetry (TRS), with pair-wise counter-propagating channels of spin-polarized electrons of opposite alignment. They have great potential for applications in the fields of spintronics and quantum computation. Further, there are intriguing predictions of a topological magneto-electric effect, a unique coupling between magnetic and electric fields that makes these materials excellent candidates for the next generation of electronic devices.

The principal strategy for making practical use of TIs is believed to be by combination with ferromagnetic (FM) materials. Introduction of magnetic order leads to TRS breaking, resulting in a gap opening at the Dirac point. This is the crucial criterion for the realization of many interesting phenomena such as the Quantized Anomalous Hall (QAH) effect and the topological magneto-electric effect as TRS breaking makes the massless Dirac electrons become massive and can change the spin orientation of the surface states near the Dirac point. Our research strategy is built on combining bulk crystal and thin film growth of ferromagnetically (FM) doped TIs and FM-TI hybrids with sophisticated structural and magnetic characterization techniques to establish and explore new materials for practical TI applications. Here, I will review our work on transition metal[1,2,3] and rare earth doping[4] of epitaxial TI thin films and bulk crystals and discuss the magnetic and structural properties of the materials.

References:

1. Collins-McIntyre, L.J. *et al*., Magnetic ordering in Cr-doped Bi_2Se_3 thin films, Europhysics Letters. *submitted*.
2. Figueroa, A.I. *et al*., Cr:Bi_2Se_3: Evidence for divalent Cr from x-ray spectroscopy, Physics Review B, *submitted*.
3. Watson, M.D. *et al*., Mn-doped Bi_2Te_3 single crystals. *New Journal of Physics* **15**, 103016 (2013).
4. Harrison, S.E. *et al*., Magnetic properties of Gd-doped Bi_2Te_3 thin films. *Journal of Applied Physics* **115**, 023904 (2014).

Email corresponding author: thorsten.hesjedal@physics.ox.ac.uk