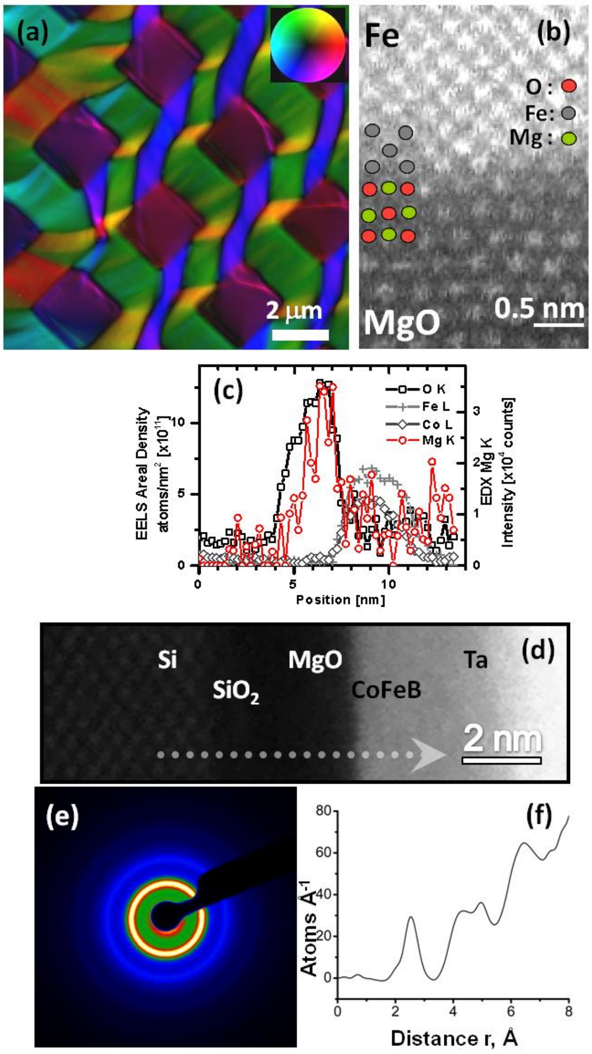
<u>Magnetic and Electronic Materials for Information Storage</u>

My research topics are in the field of magnetic and electronic materials used for information storage devices. The aim of this research is to understand how the structure and composition of these materials determines the magneto-transport properties of devices. As a result, we can improve on, or design new so-called ‘spin-electronic’ devices.

We achieve structural and chemical characterization by mostly using analytical and high-resolution transmission electron microscopy, therefore probing the properties of the material at a resolution of nanometres and up to the atomic level. In addition, Lorentz electron microscopy is applied to image the micromagnetic structure of materials and devices at the nanometre scale.

To demonstrate these research topics, several recent results are shown in the following figure:



- Remnant magnetization mapping (a) in a NiFe thin film, which was patterned by focused ion-beam. Magnetic mapping is possible due to the use of electron phase reconstruction of Lorentz TEM measurements (*Phys. Rev. B*. **72**, 014444 (2005)).

- High Angle Annular Dark-Field (HAADF) image of an epitaxial Fe/MgO/Fe tunnel junction showing atomic-column resolution (b). Consequently, the structure of the Fe/MgO interface is resolved, which is important for clarifying the mechanism for spin-dependent tunnelling (*Phys. Rev. B, **82**, 024428 (2010)*).

- A compositional profile calculated from electron energy loss spectrometry and energy dispersive X-ray spectrometry data (c), and HAADF image (d) of a SiO_2(1.5nm)/MgO(1.5nm) tunnelling barrier, developed for injection of polarised electrons from a CoFeB electrode into silicon (*Appl. Phys. Lett.*, 95, 042506 (2009), *J. Appl. Phys.,***103**, 063709 (2008))

- False colour selected area diffraction pattern (f) recorded from an amorphous CoFeB thin film, which is used widely as a ferromagnetic electrode in information storage devices. We apply reduced density function analysis of electron diffractions to measure the short range order in the amorphous material (e) and its relation to magnetic properties, such as induced anisotropy (*Phys. Rev. B*, **79**, 014203 (2009)).

Examples of current research projects are in the following topics:

Exchange-bias

Exchange bias refers to interface coupling between ferromagnetic and antiferromagnetic layers, which then results in unidirectional anisotropy. This anisotropy manifests itself by an asymmetric horizontal offset of the magnetization hysteresis curve, quantified by the so-called exchange-bias field.

Such anisotropy is of fundamental scientific interest and an important component in spin-electronic devices.

Exchange-bias is a complex interface phenomenon because in addition to the magnetic structure of the antiferromagnet, it is sensitive to structural parameters such as interface roughness, chemical intermixing, grain boundaries, and crystallographic orientation. Therefore, we employ electron microscopy to quantify structural defects and their role in determining the magnetic properties of such bilayers.

We are focusing on the Ir_xMn_{1-x} (0.15<X<0.3) antiferromagnet, which is widely used in information storage devices, comparing between sputter-deposited IrMn/$Co_{65.5}Fe_{14.5}B_{20}$ (*IEEE Trans. Magn.* **45** (2009) 3873, *Appl. Phys. Lett.,* ***96****, 072504 (2010)*), and molecular beam epitaxial growth of Fe/IrMn bilayers (*J. Phys. D: Appl. Phys.* **42** (2009) 225001).

Amorphous Ferromagnetic thin films

Amorphous materials comprised of transition metals and metalloid atoms are of technological importance; for example $Co_{40}Fe_{40}B_{20}$ (CoFeB) is used for ferromagnetic thin film electrodes in tunnel magneto-resistance sensors. These materials are ferromagnetic because exchange interactions are determined by nearest neighbour atoms. Moreover, even though the structure is amorphous, in-plane uniaxial magnetic anisotropy can be induced in CoFeB in an arbitrary direction by annealing within a magnetic field. These observations are our motivation to characterise the short-range-order of amorphous ferromagnets (*Phys. Rev. B*, **79**, 014203 (2009)).