X-ray magnetic dichroism studies of half-metallic Heusler alloys and magnetic tunnel junctions

N. D. Telling[1]; P. S. Keatley[2]; G. van der Laan[1, 5]; R. J. Hicken[2]; E. Arenholz[3]; Y. Sakuraba[4]; M. Oogane[4]; Y. Ando[4]; T. Miyazaki[4]
1. Magnetic Spectroscopy Group, STFC Daresbury Laboratory, Warrington, United Kingdom.
2. School of Physics, University of Exeter, Exeter , United Kingdom.
3. Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA, USA.
4. Department of Applied Physics, Tohoku University, Aoba-yama 6-6-05, Japan.
5. Diamond Light Source Ltd, Harwell Science and Innovation Campus, Didcot, Oxfordshire, United Kingdom.

The ability to achieve close to 100% spin-polarised materials is currently a major challenge in the area of 'spintronics' research. Such materials will have a huge impact on applications such as MRAM technology and sensors. Recently, large TMR values of 570% at low temperature have been obtained in structures incorporating Heusler alloy electrodes such as Co2MnSi [1]. These alloys have been predicted to possess a gap in the minority-spin density of states (DOS) at the Fermi level and thus be 100% spin-polarised, i.e. they are said to be 'half-metallic' ferromagnets.

The techniques of x-ray absorption spectroscopy (XAS), x-ray magnetic circular dichroism (XMCD), and x-ray magnetic linear dichroism (XMLD) provide an element-specific probe of electronic and magnetic interface states. Here we discuss the results of some recent experiments performed on Co2MnX/alumina structures (where X is Si, Al), at the Advanced Light Source, Lawrence Berkeley Laboratory. The gap in the minority-spin states leads to a local exclusion of the minority spin electrons around a given atom in half-metallic ferromagnets, i.e. the formation of an 'ideal' local moment system despite the delocalised electronic character of the material [2]. In recent work we provided the first experimental evidence of local moments on both Mn and Co atoms in Co2MnSi/alumina structures as distinct multiplet features in x-ray magnetic circular dichroism (XMCD) spectra [3].

In figures 1 and 2 are shown the XMCD spectra recorded around the Co and Mn L2,3 absorption edges for Co2MnSi (CMS) and Co2MnAl (CMA) films. From Fig.1 it can be seen that the multiplet features (indicated by arrows) are only observed in the CMS Co spectrum, whilst the CMA Co XMCD more closely resembles that from a Co/Al reference film. However the strongest multiplet feature found in the Mn XMCD spectrum from the CMS film was also observed in the CMA sample, although perhaps reduced in intensity (see Fig.2). Thus, if indeed these multiplet features are evidence of local moment formation then it appears that the Co moments are only localised in the CMS system, whilst the Mn moments are at least partially localised in both CMS and CMA films. Band structure calculations reveal that a minority-spin band gap only occurs for the Co LDOS in the CMS material, whereas both materials have a gap in the Mn LDOS [4,5]. This is entirely consistent with our XMCD results that indicate a more itinerant magnetic character of the Co atoms in the CMA sample, as can be seen by comparison of the XMCD from this sample with a standard metallic Co film.

In contrast to XMCD, the x-ray magnetic linear dichroism (XMLD) is weak in itinerant magnets (around 2% for Co), but many times larger when local moments exist [6,7]. Thus XMLD is an ideal probe of local moment formation in half-metallic ferromagnets. Our preliminary measurements of the XMLD in CMS films showed a substantial effect (~7%) at both the Co and Mn L2,3 absorption edges indicating the formation of local moments at both atomic sites. However the effect was substantially reduced at the Co L2,3 absorption edge for the CMA sample. This is consistent with the explanation given above for the more itinerant nature of Co in the CMA sample.

1. Y. Sakuraba, M. Hattori, M. Oogane, Y. Ando, H. Kato, A. Sakuma, T. Miyazaki and H. Kubota, Appl. Phys. Lett. 88, 192508 (2006)
2. J. Kübler et al, Phys. Rev. B 28, 1745 (1983)
3. N. D. Telling, P. S. Keatley, G. van der Laan, R. J. Hicken, E. Arenholz, Y. Sakuraba, M. Oogane, Y. Ando and T. Miyazaki, Phys. Rev. B 74, 224439 (2006)
4. M. Oogane et al, J. Phys. D: Appl. Phys. 39, 834 (2006)
5. I. Galanakis et al, Appl. Phys. Lett. 89, 042502 (2006)
6. A. A. Freeman et al, Phys. Rev. B 73, 233303 (2006)
7. E. Arenholz et al, Phys. Rev. B 74, 0944407 (2006).