Study of magnetic iron oxide core/shell nanocubes using electron magnetic circular dichroism

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Electron magnetic circular dichroism (EMCD) is a technique, proposed in 2003\textsuperscript{1} and experimentally demonstrated in 2006\textsuperscript{2}, which is analogous to the X-ray magnetic circular dichroism technique (XMCD) and it is based on electron energy loss spectroscopy (EELS). In the considered EMCD experiments, the dichroic signal from the magnetic material is obtained by getting a two-beam condition with two different positions for the detector, chiral plus and minus.

The EMCD main benefit in comparison with XMCD is the high spatial resolution at which the magnetic information of the sample is obtained. As in the case of XMCD, it is possible to quantitatively extract the orbital to spin magnetic moment ratio $m_l/m_S$. In our case, the EMCD technique is used to study magnetic nanocubes with a core/shell structure, formed by an iron II oxide core (FeO), 25 nm thick, covered by a magnetite shell ($\text{Fe}_3\text{O}_4$) of about 5 nm. This structure is observed in the Figure 1, where spectra of a spectrum image are classified using clustering algorithms, identifying the iron oxidation states.

The EMCD experiments are carried out in an aberration corrected S/TEM with a cold field gun at low temperature, 77 K. The two-beam condition is satisfied using the transmitted beam and $g = (002)$. In the Fe3O4/FeO nanocubes it is imperative to probe the dichroic signal from the core and shell regions separately, to characterize the magnetic properties of the magnetite shell. EEL spectra are obtained with a 0.25eV lateral resolution and classified using clustering algorithms. Once both contributions are separated, the dichroic signal from both core and shell are obtained. As no net dichroic signal is expected from the FeO region, the core region data can be used as a sanity check measure. The spin magnetic moment ratio $m_l/m_S$ is calculated for the magnetic shell. The dichroic signal obtained from these iron oxide nanocubes is presented in the Figure 2. Showing the EEL spectra for the iron L3 and L2 edges, and the resulting dichroic signal.
Figure 1. Colour map of an iron oxide nanocube resulting from the clustering analysis. The core is presented in red and the shell in blue.

Figure 2. EEL spectra showing the iron white lines from the nanocube shell. Each spectrum is acquired with the detector aperture in two different positions, chiral plus and chiral minus. In solid green, difference between both EEL spectra.

References