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EELS Analysis of Magnetic Materials

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Modern mass storage devices often rely on ever-higher density magnetic storage to provide fast access to large amounts of data. As the scale of features in these devices decreases the analysis of their structure and composition presents greater challenges to current techniques. For these materials, electron energy-loss spectroscopy (EELS) is an attractive technique [1-2] due both to its high acquisition rate and high spatial resolution. We present elemental analyses of several such materials. In some examples the multiple overlapping edges make conventional power-law fitting infeasible. In this case the multiple linear-least-squares (MLLS) [3] approach enabled us to create elemental maps.

The first sample we studied was an $Nd_2Fe_{14}B$ based permanent magnet. The microscope was a J2010 TEM equipped with a Gatan Imaging Filter (GIF, model 860). Figure 1a shows a zero-loss image of the specimen. Application of the 3-window power-law technique to the Fe L (709eV) edge and the Nd M (978eV) edge yields the elemental distribution maps shown in Figures 1b and 1c. Acquisition of the three images took 12 seconds each for the Fe map and 10 seconds each for the Nd map. Simple systems like this are quickly and easily analyzed with the 3-window technique.

A more complex problem is presented by characterization of a magnetic recording head. The sample contained many elements including Al, O, Co, Fe, Ni, Cr, W and Ta. Some of these elements are easy to map using a conventional power law approach, whereas others are not straightforward because of overlapping edges. In this example the tantalum and tungsten M edges overlap. To map these elements a series of energy-filtered images were acquired covering the range from 1200eV to 2700eV, using a slit size of 30eV and stepping the energy loss by 30eV between images. The data was then analyzed as an EELS spectrum-image (SI).

Figure 2a shows the zero-loss image of part of this device. Figure 2b shows three spectra extracted from the spectrum image taken from locations marked on this figure. A map of the aluminum distribution was generated from the K edge (1560eV) by stripping off a power-law background based on a pre-edge window. For the tungsten and tantalum we applied the MLLS technique to generate compositional maps. Two reference spectra, the M edges of Ta and of W (the two lower spectra in Figure 2b) were fitted to each spectrum in the spectrum image. This resulted in a set of combination coefficients that specify the relative contribution of each input reference spectrum at that location in the spectrum image. The resulting elemental distribution maps are shown in Figures 2c and 2d.

For complex materials such as these, EELS coupled with the spectrum imaging and MLLS techniques provides a powerful tool with which to probe the elemental distribution.

References
[1] K. Kimoto, Y. Hirayama, M. Futamoto, *Journal of Magnetism and Magnetic Materials 159* (1996) 401-405.
[2] J. Bentley et al, *Microsc. Microanal.* 7 (Suppl. 2) (2001) 1140.
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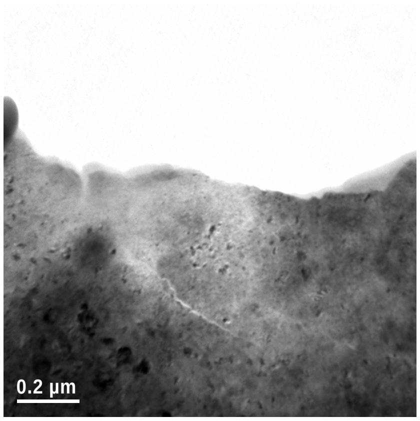

Fig. 1a. Zero Loss Image of permanent magnet

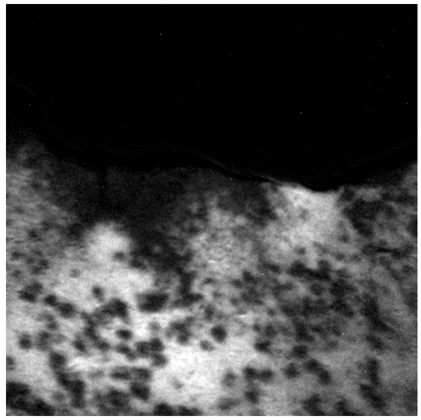

Fig. 1b. Fe map (L edge 709eV)

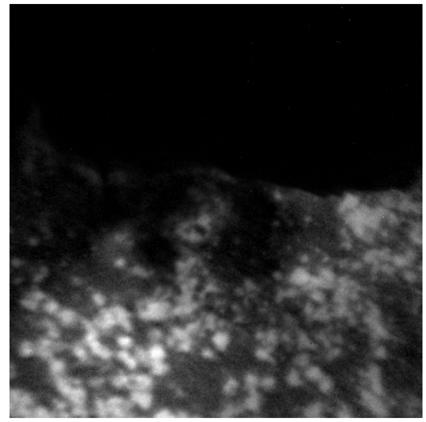

Fig 1c. Nd map (M edge 978eV)

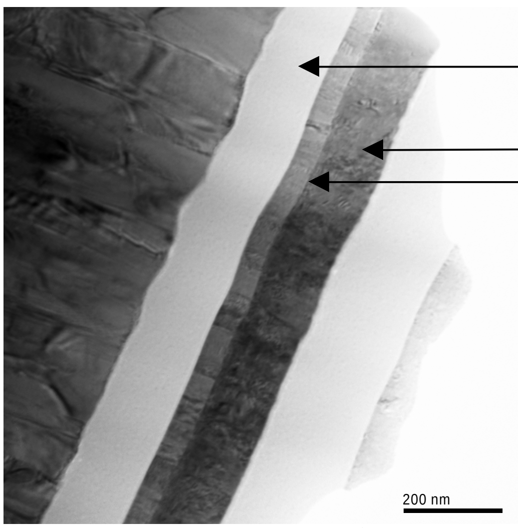

Fig. 2a. Zero Loss Image of MR head

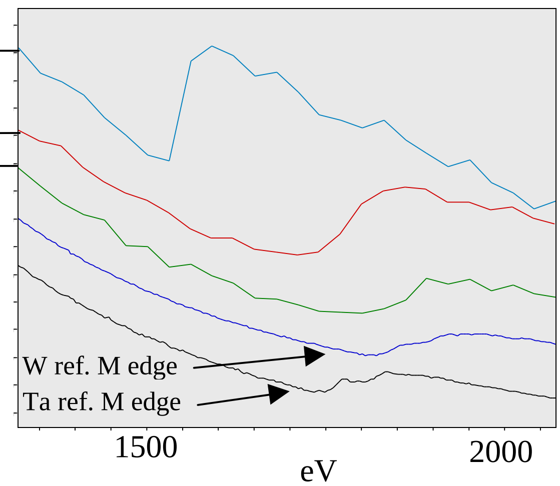

Fig. 2b. Spectrum created from SI

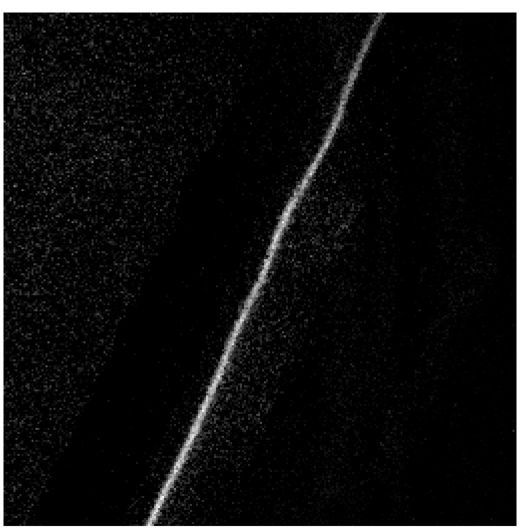

Fig. 2c. W map (M edge 1809eV)

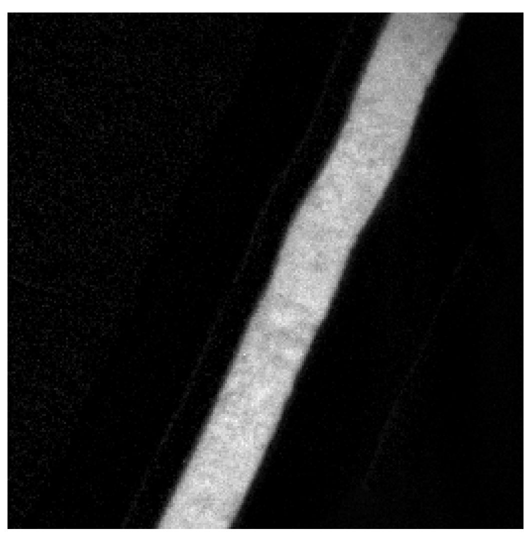

Fig. 2d. Ta Map (M edge 1735eV)

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