HYPERSPECTRAL EELS IMAGE UNMIXING

Y. Altmann[1], N. Brun [2], N. Dobigeon [3], K. March[2], S. Moussaoui[4], O. Schneegans[5]

[1]*School of Engineering and Physical Sciences, Heriot-Watt University*
Earl Mountbatten Building, Riccarton, EH14 4AS, Edinburgh, U.K.
[2]*Laboratoire de Physique des Solides, CNRS UMR 8502, Univ. Paris-Sud, Univ. Paris-Saclay*
Bât. 510, 91405 Orsay Cedex, France
[3]*University of Toulouse, IRIT/INP-ENSEEIHT/TéSA*
2 rue Charles Camichel, B.P. 7122, 31071 Toulouse Cedex 7, France
[4]*IRCCyN, Ecole Centrale Nantes*
1 rue de la Noë, BP 92101, 44321 Nantes Cedex 3, France
[5]*Lab. de Génie Élect. et Électronique de Paris, CNRS, UPMC & Univ. Paris-Saclay, CentraleSupélec*
11, rue Joliot Curie, Plateau de Moulon, 91192 Gif sur Yvette Cedex, France
nathalie.brun@u-psud.fr

Electron Energy Loss Spectroscopy (EELS) performed in a Scanning Transmission Electron Microscope (STEM) provides hyperspectral images characterized by a large number of pixels and energy channels (typically 100 x 100 x 1000) [1]. EELS enables the chemical and electronic investigation of a material at a resolution of less than 1 nm. The elements are mapped using characteristic edges falling in the loss range energy of approximately 10-2000 eV. These excitation edges exhibit fine structures providing chemical bonding information. As these structures can extend to over 50 eV, overlaps between some of the usable edge structures may occur. In addition, data often contain spatially mixed pixels. Indeed, the relevant signal corresponding to the atoms in a particular configuration (at a defect or at an interface) is generally mixed with the signal of the bulk material. Therefore retrieving the signals characterizing the different components present in the sample is essential to fully exploit the experimental data.
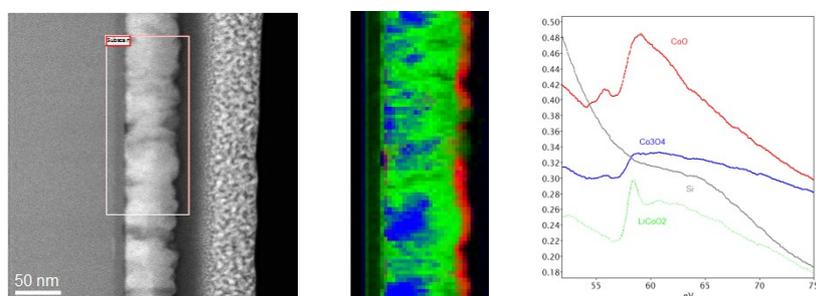

Figure 1 STEM image and maps of the unmixed components for LiCoO$_2$. Separating the intensity of Li K-edge and of Co M$_{2,3}$ edge in the 50-70 eV energy range is particularly difficult.

Various unmixing methods have been applied to the processing of hyperspectral EELS images: geometrical approaches such as VCA [2] or statistical ones such as ICA [3] and Bayesian method such as BLU [4]. The linear mixing model is the most commonly used as it generally provides relevant results. However, in complex cases where hypotheses such as a macroscopic mixing scale do not hold, considering non linear mixing models could bring a significant improvement [5].

References:
[1] A. Gloter, V. Badjeck, L. Bocher, et al., "Atomically resolved mapping of EELS fine structures," *Materials Science in Semiconductor Processing,* submitted (2016).
[2] I. Palacio, A. Celis, M. N.Nair et al., "Atomic structure of epitaxial graphene sidewall nanoribbons: flat graphene, miniribbons, and the confinement gap," *Nano letters*, 15(1), 182 (2014).
[3] F. De La Peña, M. H. Berger, J. F. Hochepied et al., "Mapping titanium and tin oxide phases using EELS: An application of independent component analysis," *Ultramicroscopy*, 111(2), 169 (2011).
[4] N. Dobigeon, N. Brun, "Spectral mixture analysis of EELS spectrum-images," *Ultramicroscopy*, 120, 25 (2012).
[5] N. Dobigeon, Y. Altmann, N. Brun and S.Moussaoui, "Linear and nonlinear unmixing in hyperspectral imaging," in *Resolving spectral mixtures - With application from ultrafast time-resolved spectroscopy to superresolution imaging*, C. Ruckebusch , Ed. Oxford, U.K.: Elsevier, Data Handling in Science and Technology Series, 2016.