Probing the chemistry of cultural heritage materials via different 2D XANES-based approaches: the alteration processes of pigments and carbonatation of calcium-based consolidants into limestone matrix

Letizia Monico,1,2,3 Marine Cotte,4,5 Koen Janssens,3 Wout De Nolf,4 Laura Cartechini,2 Francesca Rosi,2 Gert Nuyts,3 Frederik Vanmeert,1 Annalisa Chieli,1,2 Gerald Falkenberg,2 David Bati,7 Aldo Romani,1,2 Costanza Miliani.2

1 SMA Art Centre of Excellence, c/o Department of Chemistry, Biology and Biotechnology, University of Perugia, via Elce di Sotto 8, 06123 Perugia (Italy).
2 CNR-ISTM, c/o Department of Chemistry, Biology and Biotechnology, University of Perugia, via Elce di Sotto 8, 06123 Perugia (Italy).
3 AXES, Department of Chemistry, University of Antwerp, Groenenborgerlaan 171, 2020 Antwerp (Belgium).
4 ESRF, 71 Avenue des Martyrs, 38000 Grenoble (France).
5 L.A.M.S., CNRS UMR 8220, Sorbonne Université, UPMC Univ Paris 06, 4 place Jussieu 75005, Paris (France).
6 DESY, Notkestraße 85, 22603 Hamburg (Germany).
7 Centre for Art Technological Studies and Conservation (CATS), Savognol 48-50, 1307 Copenhagen (Denmark).

letizia.monico@unipg.it

In the cultural heritage field, chemical investigations are usually complicated by the fact that materials show multilayered and heterogeneous networks composed of organic and inorganic components with amorphous and/or crystalline structures that evolve with time. In this context, the use of synchrotron radiation (SR)-based X-ray micro-spectroscopic methods, including µ-XRF, µ-XANES and µ-XRD, has increased within the last few decades due to their capabilities to provide highly specific elemental and molecular speciation information with spatial resolution down to the (sub)micrometer-scale. [1-3]

Nowadays, technological research perspectives are driven by the need for time acquisition reduction in order not only to render the 2D/3D mapping of large areas more feasible but also to overcome possible damages of samples induced by the exposure to SR X-ray sources.

In general, three 2D XANES-based approaches can be used for obtaining chemical speciation information:

1) analysis of one or more regions of interest by acquiring µ-XRF maps at a few different energies around the absorption edge of a specific element in combination with collection of single-point XRF-mode µ-XANES spectra at a limited number of spots;
2) full-spectral XANES imaging in XRF-mode (by employing either traditional ED-XRF or fast X-ray detectors);
3) transmission-mode full-field XANES imaging.

These approaches have found various applications, such as the investigation of the alteration mechanisms of different artists’ pigments and the study of the manufacturing processes of ceramics. [4-11]

In this contribution, the advantages and drawbacks of the three above mentioned 2D XANES-based approaches in the context of the degradation processes of pigments (i.e. Prussian blues, chrome yellows and cadmium yellows) and of carbonatation of calcium-based consolidants into limestone matrix will be discussed.

Notably, XANES/ XRF results, in combination with µ-XRD ones, acquired at ESRF-ID21 (Grenoble, FR) and PETRA III-P06 (Hamburg, DE) beamlines from the analysis of artificially aged mock-ups and of paint micro-samples from original artworks [3,12] will be presented.