2D, 3D and 4D chemical imaging of transformation processes taking place in Heritage materials

Koen Janssens
Department of Physics, University of Antwerp, Belgium

By means of X-ray spectroscopic techniques such as X-ray fluorescence (XRF), X-ray absorption spectroscopy (XAS) and X-ray diffraction (XRD), either employing radiation generated in conventional X-ray tubes or at synchrotron facilities, it is possible to study the spontaneous chemical transformations that take place in works of art such as oil paintings, illuminated manuscripts, stained glass windows and related works of art [1]. Most of these methods employ focused X-ray beams of millimetric to nanoscopic dimensions which are scanned over relevant areas of the artefacts being examined or of (much smaller) samples thereof. Conventionally, the information these methods yield is presented in the form of two-dimensional (XY) maps showing the distribution of relevant chemical species. The latter may be specific chemical elements (XRF), elements in a specific oxidation state or chemical environment (XAS) or specific crystalline phases (XRD). To illustrate this, a few examples of the use of such maps to better understand degradation processes in well-known 17th C. and 19th C. paintings such as The Art of Painting (Johannes Vermeer, 1666-68) [2] and Intrigue (James Ensor, 1915) [3] will be discussed. However, since heritage materials usually are complex mixtures of many chemical compounds that (slowly) interact with each other and with external chemical and physical agents, it is also advantageous to employ the above-mentioned methods in a less conventional manner. One way of doing this is to employ XRF tomography at a synchrotron facility to study the elemental composition of paint microsamples in three dimensions. To illustrate the (dis)advantages of this approach, the exploration of paint samples taken from Rembrandt's masterpiece The Nightwatch (1642) will be discussed [4]. Another less conventional way of using 2D XRD-micro mapping is to do this in a time-resolved manner, leading to three- or four-dimensional (X or XY, time and scattering angle) datasets. Such type of experiments, which can be performed either in the lab or at a synchrotron facility, allow to follow the gradual oxidation of lead white, a commonly used painter's pigment with an oxidizing gasses such as Cl2, HOCl and SO2. These substances has been demonstrated to be the cause of chemical pigment degradation in 13-17th C. works of art [4,5]. Acknowledgement: This work was supported by InterReg project SmartLight 2.0 and by FWO-SBO (Brussels) project AutomatED.

References:

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