

Imaging of alteration and degradation processes in 13th-20th c. works of art by MA-XRPD and related methods

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Macroscopic powder diffraction (MA-XRPD) and X-ray fluorescence (MA-XRF) are forms of non-invasive hyperspectral imaging that allow to obtain information on painted works of art, in the form of phase specific or elemental images. By means of these methods the following can be done:

- re-visualization of overpainted representations, revealing early stages of the creative process or intentional alterations of the composition done during the lifetime of the artwork;
- (highly specific) identification of the pigment types used and the pigment subtypes present, providing opportunities to study the provenance and authenticity of works of art; and
- identification of the nature and distribution of secondary products, formed on the paint surface by degradation of the original painting materials.

In the past decade we have imaged a variety of (renowned) paintings, mainly in European museums. In a number of cases, macro-scale information was combined with (X-ray based) micro-analysis of paint samples,

After describing the principles of MA-XRPD and MA-XRF, several recent case studies will be discussed, including

- (a) imaging the spontaneous degradation of the pigments of the 13th vault paintings in the Basilica of St. Francis in Assisi, IT [1];
- (b) scanning highlights of 17th c. Dutch art such as Rembrandt's Nightwatch (1643) [2,3] and
- (c) determining the nature and degradation behavior of pigments in works by 19/20th c. painters such as Vincent Van Gogh, Robert Delaunay and Edvard Munch [4,5].

[1] Avranovich E., et al., (2023) *Molecules*, **28**, 6106.

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[4] Mayda, S., et al. (2023) *Chem. Mater.*, **35**, 10403–10415.

[5] Gonzalez V., et al. (2025) *J. Am. Chem. Soc.*, **147**, 2587–2596.

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