New Perspectives in Cultural Heritage Research through Spatially Resolved Energy-Dispersive Inelastic X-ray Scattering Spectroscopy

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The investigation of cultural heritage samples poses significant challenges due to their intrinsic heterogeneity, stratified nature and complexity, together with the requirement for non-destructive analytical methodologies. In this lecture, recent advances in spatially resolved Energy-Dispersive Inelastic X-ray Scattering (EDIXS) spectroscopy are presented, highlighting their relevance and potential impact on cultural heritage research.

The talk will first introduce the physical principles underlying EDIXS, emphasizing its connection to Resonant Inelastic X-ray Scattering (RIXS) and its distinctive operational features. By working at fixed incident energy, EDIXS avoids energy scans, reducing acquisition times and minimizing self-absorption effects that often limit conventional X-ray absorption techniques, as XANES and EXAFS. These characteristics make EDIXS particularly suitable for the study of complex and radiation-sensitive materials commonly encountered in artworks and historical objects.

The methodological foundations of spatially resolved EDIXS will then be discussed, with special attention to the role of multivariate statistical analysis in extracting chemically relevant information from RIXS spectra. Multivariate tools such as Principal Component Analysis (PCA) and advance classification methods are essential for discriminating subtle variations in chemical state and local atomic environment, especially when dealing with compounds of the same element distributed in heterogeneous systems. The exploitation of the fine spectral structure of RIXS emission lines enables micrometric-scale chemical mapping in two-dimensional geometries, with straightforward extensions toward three-dimensional (confocal) configurations.

Selected case studies from the analysis of paintings and philatelic materials will be presented to illustrate the capabilities of the technique. In pictorial samples, EDIXS allows the identification and spatial discrimination of different copper-based pigments in mixed layers, providing insight into pigment composition and related processes. In historical postal stamps, EDIXS enables the differentiation of iron-based inks and the definition of characteristic chemical signatures associated with specific historical periods, with potential applications in authentication and forgery detection.

Learning Outcomes: Overall, this lecture aims to provide a quick overview of the physical basis, analytical methodology and potential applications of EDIXS spectroscopy. The results discussed can be effectively transferred to interdisciplinary research, opening new perspectives for the non-destructive study of cultural heritage materials.

Intended Audience: The intended audience for this lecture includes advanced students, PhD candidates, researchers and professionals with, ideally, a background in radiation–matter interaction, with prior knowledge of X-ray spectroscopy techniques. The lecture is aimed at participants interested in advanced analytical methods and complementary spectroscopic approaches for cultural heritage studies, as well as at those who require state-of-the-art techniques for the characterization and interpretation of historical and artistic materials.