Going beyond XRF: Use of micro-fluorescence and diffraction to understand how a cultural heritage object was made and how it ages and degrades

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The ability to see an object at higher resolution, or with improved contrast than possible by the un-aided eye has revolutionized our understanding of how certain objects are constructed and how this construction aids in their function. and over last millennium every advance in microscopy, be it in the spatial resolution or in the contrast mechanism, has resulted in a revolution in a discipline of science.

When a sample is excited with high energy x-rays (or electrons), photons are emitted at wavelength (photon energies), which are characteristics of the elements present in the excited sample. X-ray Fluorescence (XRF) microscopy provides a contrast mechanism that helps identify chemical composition, and variation of chemical composition in the sample. With advances in electron and x-ray optics and sources, progressively smaller probe beams have been available for XRF microscopy, and over the last couple of years, DXC has highlighted many of these advances in technology and the revolutionary impact it has had on our understanding of how complex objects are put together and how they age and degrade.

The chemical composition, the microscopic three dimensional arrangement of the building blocks and the ageing process of a cultural heritage object, not only gives us an insight into the mind of the artisan and a glimpse into the sociology, trading practices and economy of their world, but it also helps us preserve that whole class of artefact for future generations to study and admire. XRF microscopy has played, and will continue to play a very large role in study of cultural heritage materials.

But often the most interesting and crucial variation in the chemistry of an object is not in its elemental composition, but in its phase chemistry. For example, while investigating a sherd of red and black illite based Attica pottery, it is not only sufficient to know that the glosses are rich in Fe, Al, and K, but essential for an understanding of conditions of firing sequence whether the black gloss we are looking at is hercynite or composed of a fine mixture of magnetite and corundum. Or while devising a method for preserving ancient, water-logged, and sulfur enriched wood we need to know not only the amount of sulfur enrichment but its chemical speciation in the wood.

Advances in microscopy at 3rd generation synchrotrons has made it almost routine to collect a map of x-ray absorption spectra (XAS) or microdiffractograms, often simultaneously with an XRF elemental map. Different phases, even with very similar composition, almost always have very different XAS spectra or a diffractogram, and hence they provide contrast mechanisms that are phase sensitive. In this talk, we will present, with examples from the art and archeology, the power of combining XAS, and microdiffraction imaging with XRF and EDS microscopy.