Non-destructive SR techniques: Current and future applications

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Highly intense X-ray beams as produced at synchrotron radiation facilities, that often are also highly monochromatic and have a low divergence, are highly suitable tools for examining fragile, valuable and/or unique artefacts with minimal or no damage. Depending on the nature of interactions the impinging X-ray photons are subject to and the type of detectors that are employed to record the result of such interactions, information of different nature can be obtained on the materials or objects being investigated. This information can be about the major- and trace-level composition of the objects, about the chemical state of one or more atomic species that are present and/or about crystallographic phases on the materials.
Since the materials and objects encountered in the field of art-analysis, archaeology and conservation are often complex in shape, covered with alteration layers and/or may be highly heterogeneous, the use of X-ray micro beams is very often required to allow for the measurement of local rather than bulk properties. Elemental microanalysis down to the sub-ppm level is possible in two or three dimensions by means of conventional or confocal μ-XRF (X-ray fluorescence analysis). Local chemical state determinations of selected (trace) constituents are possible by applying μ-XAFS (X-ray absorption spectroscopy) while information on the presence of (sub)microscopically small crystalline phases can by obtained via μ-XRD (X-ray diffraction) and μ-SAXS (Small angle X-ray scattering). These methods usually employ X-ray photons with energies in the 0.5 to 30 keV range.
Alternatively, entire objects may be bathed in highly-energetic synchrotron beams to allow high quality radiographic or tomographic imaging measurements, revealing the internal structure of these artefacts.
On the other side of the wavelength- or energy scale, also the infra-red radiation produced by synchrotron facilities is starting to be used for investigation of ancient materials in FT-IR (fourier-transform infra-red spectroscopy) microscopes adapted for this purpose.

In this introductory presentation, an overview of the above-mentioned SR-based methods will be given, briefly illustrated with examples taken from the recent literature, with special attention for the micro- or non-destructive aspects of each technique. Additionally, the complementarity between these SR-based techniques and (non-destructive) laboratory-based methods of investigation (such as the various forms of electron microscopy) will be discussed.