Use of Synchrotron Radiation to Examine Heritage Materials: Monitoring and Characterization of Radiation-Induced Side Effects

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Synchrotron radiation based x-ray techniques are increasingly used for spectroscopy and imaging of ancient and cultural heritage materials, in particular to perform macro-scale composition and speciation imaging on fossils or works of art without the need to collect samples. Synchrotron techniques are often desirable since the experiment can tune the x-ray energy to the optimal value for the measurement. The increasingly high brilliance of new x-ray source is reflected in an increase in synchrotron-based usage in this field of cultural heritage. While the increased brilliance has helped to drive the accessibility of experiments to more difficult materials, it also has a stronger potential to no longer be a non-invasive technique due to the high level of radiation exposure. In order to develop proper mitigation strategies, and to develop techniques to monitor potential damaging side effects of radiation exposure, research needs to focus on gaining a better understanding of the physico-chemistry of potential damage mechanisms in complex cultural heritage samples.

As one of the most desired and expensive artists' materials throughout history, there has long been interest in determining the chemistry responsible for the blue hue of the ultramarine pigment. Sulfur K-edge XANES has been particularly suited to characterize the sulfur radical species identified as the chromophore of the pigment. The potential lability of sulfur radicals has motivated this research into assessing the effect of possible radiation damage to S-based species. Radiation damage tests were carried out using unfocused and focused x-ray beams on lapis lazuli rock and a series of three different grades of extracted pigments in order to define the optimal acquisition parameters to allow safe analyses of ultramarine pigments. Calculation of the dose applied to the sample allows a kinetic analysis of the radiation-induced effects, showing that the induced damage follows first-order kinetics with respect to the polysulfide radical species. These results show the reactivity of lapis species in the x-ray beam and allow a first assessment on the acceptable amount of radiation exposure.