X-ray Raman scattering: a hard X-ray probe for the study of cultural and natural heritage

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Deciphering the chemical nature of carbon-based compounds in ancient materials is now possible in three dimensions [1]. We use X-ray Raman imaging (XRI), a novel synchrotron-based hard X-ray technique first proposed by Huotari et al. [2], to visualize at each point the chemical composition of a 53-million-year-old ant preserved in amber (Fig. 1A). The 3D XRS-based imaging highlights the presence of two distinct chemical fingerprints in the exoskeleton (Fig. 1B): the first being molecular signatures of chitin, the main structural component of insect's exoskeleton and the second aliphatic carbons, a product of burial diagenetic transformation of the original chemistry of the organism. The results point to the importance of complete characterization of paleontological specimens, at a global scale, to provide information about the specimens' biochemistry, molecular evolution, and chemical interactions between the organism and the depositional setting.

The capabilities of X-ray Raman spectroscopy also provide new insights in the analysis of organic materials in cultural heritage studies [3]. We use carbon K-edge XRS-based spectra towards characterizing chemical fingerprints of native resins from a historical collection. This study opens new perspectives on non—invasive identification and statistical clustering of organic materials based on their plant genera, with the potential to identify resins on Aboriginal Australian cultural heritage materials.

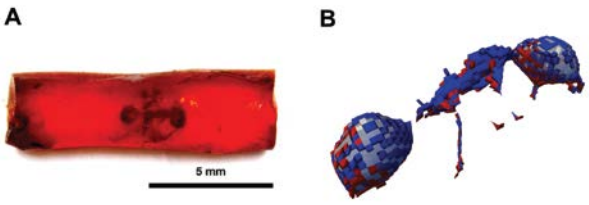

Figure 1: XRS 3D carbon K-edge speciation mapping of an Eocene ant (ca. 53 Mya) entrapped in Oise amber

References

[1] Georgiou et al. "Carbon speciation in organic fossils using 2D to 3D x-ray Raman multispectral imaging." Science advances 5.8 (2019): eaaw5019.

[2] Huotari et al. "Direct tomography with chemical-bond contrast." Nature materials 10.7 (2011): 489.

[3] Gueriau et al. "Noninvasive Synchrotron-Based X-ray Raman Scattering Discriminates Carbonaceous Compounds in Ancient and Historical Materials." Analytical chemistry 89.20 (2017): 10819-10826.