Spectromicroscopy study of mineral-microbe interactions by soft x-ray scanning transmission x-ray microscopy

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Microorganisms can form minerals, which usually have peculiar features compared to abiotically formed minerals. For example, biominerals may have a poor crystallinity or alternatively show the absence of lattice defects; they sometimes show mesocrystallinity (i.e., clustering of nanodomains with a common crystallographic orientation resulting in an apparent single crystal at a larger scale), association with organic molecules at the nanometer scale, major and/or trace element composition departing from what is expected in abiotically precipitated minerals, a particular textural arrangement, and/or particular morphology. Characterizing these particular features and understand their origin is of great interest to various scientific field including medical sciences, chemistry, environmental sciences or the search of past traces of life.

Achieving those goals requires an advanced characterization of both organic molecules and minerals at the scale at which the processes operate, that is, the submicrometer scale. Here, we will show how synchrotron-based soft x-ray scanning transmission x-ray microscopy (STXM) proves as an interesting tool for that purpose [1]. This microscopy technique provides chemical speciation-sensitive images at a spatial resolution down to ~15 nm coupled with x-ray absorption near-edge spectra (XANES) over a relatively extended range of energies (between 100 and 2000 eV). Samples can be analyzed at ambient pressure. Soft x-ray STXM allows characterizing the speciation (i.e., coordination or redox state) of various elements including the major elements composing organic molecules (e.g., C, N, O, S, and P) and various metals forming biominerals (e.g., Ca, Fe).

We will illustrate the spectroscopic capabilities of STXM by showing a study at the Ca and P $L_{2,3}$-edges on Ca-phosphate biominerals [2] and another study at the Fe $L_{2,3}$-edges to follow the oxidation of Fe(II) by bacteria [3, 4]. We will then show how linear dichroism can be used to map the crystallographic orientation of biominerals. Recent advances such as STXM-tomography and the use of x-ray fluorescence detection in STXM to analyze trace elements will also be presented as well as a brief overview of the available facilities, including STXM on the HERMES beamline at SOLEIL.

Références

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