Deciphering biomineralization pathways with a new x-ray Bragg microscopy

V. Chamard

Aix-Marseille Université, CNRS, Centrale Marseille, Institut Fresnel UMR 7249,
13013 Marseille, France

virginie.chamard@fresnel.fr

Biomineralization processes result in the production of outstandingly complex mineralized structures in living organisms (e. g., teeth, bones, shells, etc.). While they are still poorly understood to date, deciphering these mechanisms is of crucial importance: in materials science, it should provide bio-inspired strategies for the synthesis of nanostructured inorganic materials using soft chemistry and environmentally friendly processes; in paleoclimatology, strong impacts are also expected due to the use of biomineral proxies to perform paleoclimate reconstructions. On the contrary to the classical crystallization theory scheme, the production of most calcareous crystalline biominerals integrates several complex processes, likely based on the generic formation of a submicrometric granular structure. Hence, gaining access to the crystalline architecture at the mesoscale, *i. e.*, over a few granules, is key to building realistic biomineralization scenarios. This is hindered by the difficulty to image complex crystalline materials at the nanoscale, one of today's major challenges of nanoscience.

Answering this need would require a microscopy method combining sensitivity to the crystalline properties, 3D imaging capability, *in situ* compatibility and high spatial resolution. In this context, the recent advents of x-ray lensless imaging methods, based on Bragg coherent diffraction at third generation synchrotron sources, have opened promising perspectives, filling the gap between direct microscopies (AFM, SEM, TEM) and reciprocal-space based x-ray Bragg diffraction analysis. The decisive answer has been brought by 3D Bragg ptychography microscopy [2], which merges concepts developed in inverse microscopy and crystallography. This x-ray Bragg microscopy fully meets the requirements imposed by the structural investigation of biominerals.

In this presentation, the general concepts of Bragg ptychography will be detailed, illustrated by recently proposed developments [2-7]. I will further describe how Bragg ptychography can be exploited to bring new insights on the biomineral crystalline structure. Perspectives with respects to the understanding of the biomineralization mechanisms will be finally presented [8].

This project has received funding from the European Research Council (ERC) under the European Union's Horizon H2020 research and innovation program grant agreement No 724881.

References

[1] M. A. Pfeifer, *et al*., Nature **442**, 63 (2006). A. Ulvestad, *et al*., Science **348**, 1344-1347 (2015).
[2] P. Godard, *et al*., Nature Communications **2**, 568 (2011).
[3] P. Godard, *et al*., Optics Express **20**, 25914 (2012).
[4] F. Berenguer, *et al.*, Physical Review B **88**, 144101 (2013).
[5] A. I. Pateras, *et al*., Physical Review B **92**, 205305 (2015).
[6] V. Chamard, *et al*., Scientific Reports **5**, 9827 (2015).
[7] S. O. Hruszkewycz, *et al*., Nature Materials **16**, 244 (2017).
[8] F. Mastropietro, *et al*., Nature Materials **16**, 946 (2017).