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Ptychographic soft x-ray spectromicroscopy of biominerals: mapping chemistry and crystal orientation with few nanometer spatial resolution

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The Advanced Light Source (ALS) at Lawrence Berkeley National Laboratory has developed ptychographic soft x-ray spectromicroscopy for x-ray analysis of chemical states in nanomaterials at few-nanometer resolution. Soft x-rays provide exquisite sensitivity to the chemical bonding environment in materials and when coupled with nano-imaging can provide high resolution maps of both chemical speciation and bond orientation [1]. Speciation can be probed by tuning the x-ray energy to specific absorption resonances whereas orientation is probed by rotating the x-ray polarization to utilize dichroic contrast. Polarization dependent contrast is a powerful tool to analyze crystal orientation in biominerals such as calcium carbonate which exhibits strong anisotropy due to the carbon and oxygen bonds [2]. This technique has been very successful at studying biomineral systems in a reflection geometry with surface sensitivity but it has not been widely deployed in a transmission geometry which would be needed for studying the three dimensional character of materials. At the coherent imaging beamline of the ALS, beamline 7.0.1.2 COSMIC, we have implemented dichroic imaging of biominerals in a transmission geometry in order to enable three dimensional mapping of crystal orientation [3,4]. Furthermore, we have coupled this with ptychographic imaging which gives both higher spatial resolution of about 10 nanometers and also the novel use of phase contrast for polarization dependent contrast mapping. We show that the angular resolution for crystal orientation measurements is as good as 5 milliradians and we apply the method to study the angular distribution of aragonite crystallites from coral. We discovered that the distribution of orientations is multi-modal where smaller domains are differently oriented from the main spherulitic crystals [5].

References

1. Ade, H., *et al, Nature Materials* 8, 281–290 (2009)
2. P. U. P. A. Gilbert, *et al, Proc. Natl. Acad. Sci. U.S.A.* 108, 11350–11355 (2011)
3. David A. Shapiro *et al., Sci. Adv.,* **6**, eabc4904 (2020)
4. Vanessa Schoeppler, *et al,* Proceedings of SPIE Volume 11839, X-Ray Nanoimaging: Instruments and Methods V; 118390D (2021)
5. Y.H. Lo, *et al, Proc. Natl. Acad. Sci. U.S.A.* 118 (3) e2019068118 (2021)