Contribution ID: **5** Type: **Talk**

Multimodal X-ray imaging of biological specimens

Monday, 22 June 2020 16:00 (20 minutes)

Structural investigations of biological systems often involve the application of several highly sensitive and complementary methods able to provide statistically significant results. X-ray ptychography [1] is a robust and promising scanning coherent-diffraction imaging technique, yielding quantitative optical density contrast at dose-limited spatial resolutions beyond the fabrication limits of X-ray optics. Its scanning nature allows for simultaneous X-ray fluorescence (XRF) mapping, that enables artefact-free correlations of trace elements with highly resolved specimen's morphology [2,3]. Moreover, ptychography can also be combined with computed tomography, yielding quantitative 3D electron-density maps of extended specimens down to sub-100-nm spatial resolutions [4]. Thanks to its sensitivity, ptychography is particularly suitable for imaging biological tissues and cells, whose irradiation sensitivity sets a stringent requirement for highly efficient use of every X-ray photon they interact with. By using high-quality coherent X-ray beams, low-background setups, and optimized scanning routines, multimodal scanning X-ray microscopy aspires to an excellent tool for high-resolution structural investigations of weakly absorbing sub-cellular structures in 3D.

Here, we present the application of ptychography with concurrent XRF mapping at beamline P11 at the low-emittance synchrotron storage ring PETRA III, DESY. We developed a scanning X-ray microscope featuring a Fresnel zone plate as an illumination-forming optic, high-throughput scanning unit, and a high-framerate detector. We used the correlative method to image a population of macrophages treated with iron-oxide nanocontainers for tuberculosis drugs. We further applied the concurrent imaging techniques to study the mineralization of a human bone matrix [5]. Recently, we have upgraded our X-ray microscope with a rotation stage permitting ultrafast tomographic measurements. We will demonstrate its operation with ptychographic tomograms of representative specimens. Finally, further applications, in reference to emerging diffraction-limited synchrotron light sources, will be addressed.

References

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