X-ray imaging, microscopy and tomography on EMBL beamline P14 at PETRA III

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EMBL Hamburg operates the P14 beamline at the high-brilliance PETRA III storage ring at DESY. Delivering hard X-rays (6 – 30 keV), P14 is very versatile: shape, size and intensity of the X-ray beam are easily tunable by using both reflective and refractive optical elements. Sample stage and detecting systems are state-of-the-art including a high-precision vertical goniometer, a robotized sample changer and a Dectris Eiger 16M detector. These features enable crystallography of large macromolecular complexes, serial crystallography, time-resolved and in-situ diffraction data collection.

Exploiting the flexibility of the beamline optics, we are investigating new methods and techniques to look into samples of interest via full-field phase-contrast X-ray imaging [1] and microscopy. Unlike conventional absorption X-ray imaging, phase contrast makes interfaces and density gradients clearly visible in a biological sample. To achieve higher resolution and to see fine structure, we also implement X-ray refractive lenses [2] as an objective in the microscopy mode. This approach allows us to magnify details of the sample up to 15 times prior to the optical detection of X-rays that carry the phase-contrast information from the interaction with sample. With the current setup, a sub-100nm resolution can be achieved. High-precision rotation of the sample stage at P14 also allows to perform X-ray tomography. Due to the use of high-energy X-rays for the imaging process, materials and tissues with thicknesses in the mm-range can be penetrated.

The described setup apply phase-contrast imaging techniques for full-field visualization and fast X-ray tomography of crystals in optically opaque mesophase with sub-micron resolution at low dose (Fig. 1). With the help of the method, it is possible to visualize crystal boundaries and their local deformations in situ, thus supporting the most challenging MX applications. In addition to crystallographic applications, the imaging assembly at P14 is used for investigation of multi-cellular organisms. The short time-scale for completing measurements and the existing automation of P14 allow us to apply high-throughput X-ray tomography, providing a way for large-field-of-view screening of biological samples prior to further high-resolution electron microscopy studies.

Fig. 1. (a) X-ray phase-contrast imaging (a), tomography (b) and segmentation (c) of LCP-embedded crystals