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Multi-Scale Imaging at the Coherence and Imaging Beamline I13 at Diamond

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The Diamond I13 imaging and coherence beamline performs multiscale imaging and tomography with phase sensitive imaging methods. Operating in the energy range of 6-30keV, the achievable resolution ranges from several microns to tens of nanometers [1,2]. The beamline is unique in combining imaging methods in real and reciprocal spaces, which are available on two independently operating branchlines. The scientific program is currently being developed with the distinct capabilities offered by the beamline. Most recently ptycho-tomography has become operational and a multitude of scientific projects is linking the research between both branchlines.

The Diamond-Manchester imaging branchline performs mainly in-line phase contrast microtomography with a strong emphasis on dedicated sample environments. Failure of lithium batteries, material cracks, structure of ice cream, bones under load, and storage of CO_2 in brine and sandstone are some examples studied under realistic conditions. Most experiments are carried out in the so-called polychromatic 'pink-beam' mode, with micron resolution and milli-second exposure times. Furthermore, a multilayer and a Si (111) monochromator are available for element selective measurements. Two additional projects (full-field microscope and grating interferometry) are currently under development for studies with submicron resolution and phase sensitive imaging.
The full-field microscope can perform Zernike phase contrast imaging over a field of view of 50-100µm with a resolution of 50-100nm. The large working distance over several centimeters enable a large variety of scientific applications with dedicated sample environments [3,4]. The different stripes of the multilayer monochromator provide a bandwidth between $\Delta E/E=10^{-3}$ and 10^{-2} and combined with a fibre-optic plate coupled sCMOS detector, exposure times of few 100ms are achieved.
Grating interferometry provides superb image quality, measuring the absolute phase and providing small angle information. We currently plan to apply this method to identify nano-sized structures with micrometer resolution [5,6], as for example in the studies on bones, battery materials, pharmaceutical products or industrial filter materials.
Highest spatial resolution is achieved on the coherence branch with ptychographic imaging with 30nm spatial resolution. The photon counting EXCALIBUR detector can continuously record with a speed of up to 250Hz over an array of 1.5x2kPixels. After the last year of development the recording speed for ptycho-tomography scan has significantly improved. A full scan currently takes a few hours and is anticipated to be further accelerated. Ptychography is now performed as standard user experiment, enabling the beamline's ambition for multi-scale imaging. A large number of pilot experiments are being

explored, with many being carried out at the imaging branch previously. Examples include the studies of battery failure, the origin and structure of particles from the Fukushima accident, and the micro- and nano-structure of insects or polymer materials. For nano-crystalline samples we are developing Bragg-CDI. Some original instrumentation is used such as a robot-arm detector positioning system [7]. The scientific output of the beamline is also enhanced by the data analysis facility [8]; users are re-invited on site, ensuring the timely evaluation of data under competent guidance.
As example for the beamline capabilities, some reconstructed slices and a projection of nano-cellular polymers are shown in figure 1. The material contains gas enclosure within the polymer on the sub-micron and nano-scale (30-500nm). The aim of the study is to improve the understanding between the properties and the structure of the material [9].

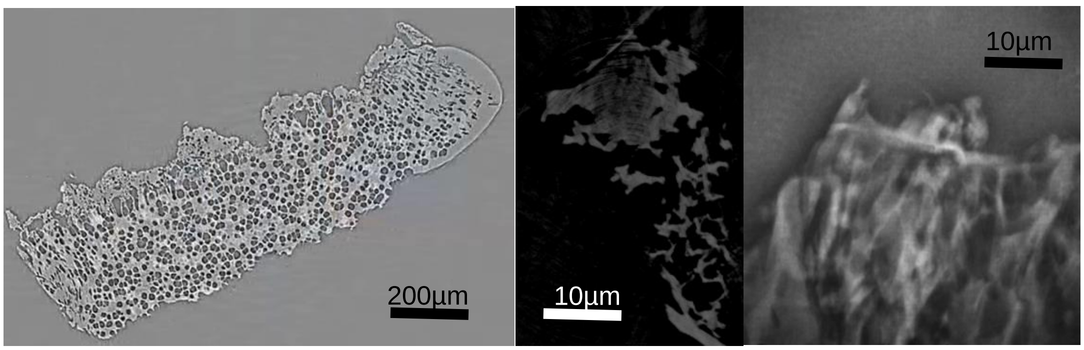

Figure 1: Reconstructed slices of micro/nano-cellular polymers recorded with in-line phase contrast imaging and ptychography, projection image with full-field microscope (from left to right).

In summary the beamline uniquely combines techniques in real and reciprocal spaces, enabling imaging from the micro- to the nano-lengthscale. Some more examples for the large number of scientific applications with dedicated sample environments can be found elsewhere [10][11].

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