Bragg Coherent Diffractive Imaging: An Everyday Microscopy Tool?

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Bragg Coherent Diffraction Imaging (BCDI) is a coherent X-ray diffraction technique that allows the non-destructive probing of morphology and lattice distortion of crystalline materials with sub 10 nm 3D spatial resolution. Because it does not require optics close to the sample, BCDI is perfectly suited for insitu experiments. For example, it has been used to study phase transformations, the effects of crystal defects, crystal growth and degradation. The increase in coherent flux afforded by the ESRF upgrade will open up the opportunity to use coherent diffraction on many more instruments. As such BCDI could/should become an everyday tool for the broad, non-specialist material science community. For this to happen a number of key challenges need to be addressed:

BCDI requires that samples are crystallographically-isolated, and fit within the coherent volume of the X-ray beam (less than 1 um^3). Thus far this has limited BCDI to materials that naturally form micro-crystals of a suitable size, placing the vast majority of technologically interesting materials out of reach. Using focussed ion beam milling (FIB), we recently demonstrated the ability to manufacture micron-sized samples for BCDI from larger crystals. The FIB technique is highly site specific, making it possible to position specific micro-structural features of interest within these samples [1].

BCDI on a single crystal reflection provides one component of the lattice displacement field. By measuring at least three-independent reflections, the full lattice displacement and hence lattice strain tensor can be recovered. This is a unique capability. For reliable multi-reflection BCDI (MBCDI) measurements, the ability to quickly locate and rapidly orient specific crystals is key. We have developed approaches to this end, e.g. using micro-beam Laue diffraction to pre-orient specific crystals [2].

A major bottleneck for BCDI is reliable phasing of the collected diffraction patterns. Furthermore, the analysis of MBCDI data is complicated for samples containing crystal defects, such as dislocations, that give rise to phase jumps. Recently we have developed new tools to allow the straightforward reconstruction of the full lattice strain tensor using MBCDI, even in the presence of extended dislocation structures [1].

I will summarise recent developments in these areas, illustrated with examples and applications, concentrating on crystal defects and irradiation damage [3, 4]. I will also provide an outlook of the most pressing challenges, from a user perspective, for making (M)BCDI a general microscopy tool. These include the need for integrated sample manufacture and measurement, the urgent requirement for more robust phasing approaches and optimisation of high-throughput measurements.

References

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