Diffraction-Based Characterization of Local Structure In Three Dimensions Under Operand Conditions And In Real Time

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Since the advent of X-ray diffraction, reciprocal space methods have been used to measure average properties to a high precision. Generally periodic samples are necessary to extract atomic-level information, although more recently developed methods such as pair-distribution function (PDF) analysis can be extended to non-crystalline or semi-crystalline samples, allowing the characterization of local structure of in principle any material. The field of PDF analysis is now mature, and increasingly complex and heterogeneous materials or systems such as batteries, fuel cells and catalytic reactions can be studied under *operando* conditions with very high (down to 10s of millisecond) time resolution. More simple systems can be studied under extreme conditions of, for example, very high temperature or pressure.

In contrast**,** direct space methods can probe directly local inhomogeneities. The extension of these methods, which entail scanning with an X-ray beam of size on the length scale of the phenomena of interest, to shorter length scales is a serious but achievable technical and analytical challenge. With direct resolution in two dimensions of better than 100 nm, the gap between length scales amenable to study by direct and reciprocal space methods has closed, and it is now possible to thus study local variations in short range order. Furthermore, due to recent developments in diffraction-based tomographic reconstruction techniques, even three dimensional information can now be acquired at the length scale of a few microns on real, working systems, on both crystalline and amorphous materials.

We will describe recent results and current projects currently underway to allow the total multi-scale characterization of complex heterogeneous systems via these local probes on a new dedicated instrument.